REPORT

OF THE

WATER SUPPLY COMMISSION

OF

PENNSYLVANIA.

1907.

HARRISBURG, PA.:
HARRISBURG PUBLISHING CO., STATE PRINTER.
1908.

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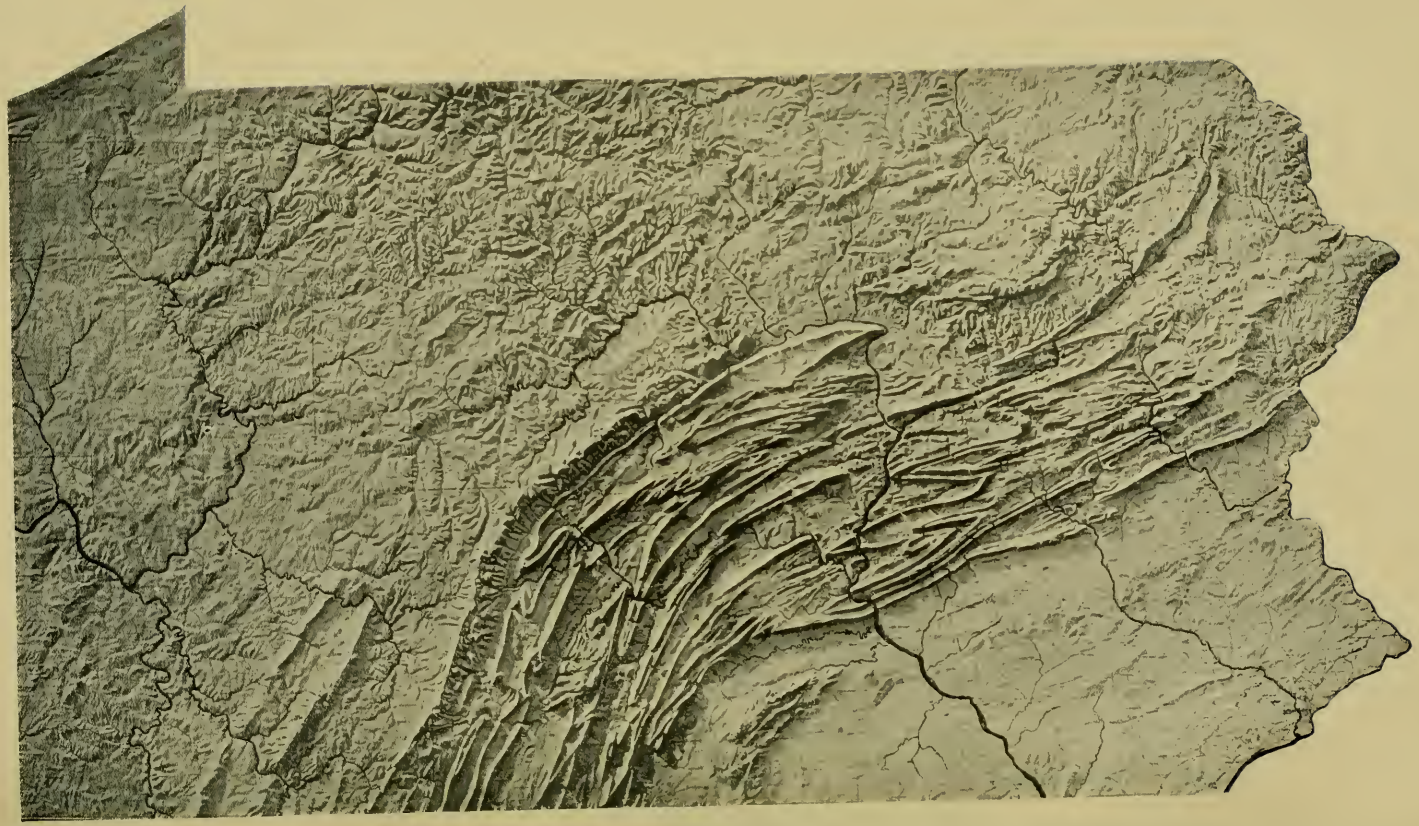

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WATER SUPPLY COMMISSION OF PENNSYLVANIA.

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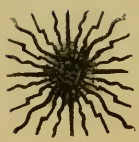
The Commission wishes to express its thanks to the various State Departments, the Hydrographic Branch of the United States Geological Survey, the United States Weather Bureau, Philadelphia Bureau of Water and to the various municipal organizations, corporations and individuals who have supplied information embodied in this report.



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REPORT

OF THE

WATER SUPPLY COMMISSION OF PENNSYLVANIA.

Office of the Water Supply Commission,
Harrisburg, December 31, 1907.

To the Honorable Edwin S. Stuart, Governor of the Commonwealth of Pennsylvania:

To the Members of the Senate and the House of Representatives of the Commonwealth of Pennsylvania:

In compliance with the provisions of the Act of the General Assembly of May 4th, 1905, we have the honor to submit herewith the report of The Water Supply Commission of Pennsylvania, for the year 1907.

Section 1 of the said Act provides:

For the creation of the Water Supply Commission to consist of five members, three of whom shall be appointed by the Governor, and the two remaining members of the Commission shall be the Commissioner of Forestry and the Commissioner of Health, to be called and known as The Water Supply Commission of Pennsylvania.

Section 3 of said Act, among other things, stipulates as follows:

"It shall be the duty of the Commission to procure, as speedily as may be, all the data and facts necessary to advise them thoroughly of the situation of the water supply of the State, and adopt such ways and means of utilizing, conserving, purifying, and distributing such water supplies in such a way that the various communities of the State shall be fairly and equitably dealt with in such distribution: Provided, however, That the local distribution of water within the limits of an incorporated village, town or city is not to fall within the jurisriction of this Commission."

Section 5 of said Act is as follows:

"Hereafter no letters patent shall be issued to any company desiring to be incorporated for the purpose of supplying water to the

public, in any community in the Commonwealth, until said application is first submitted to and has received the approval of a majority of the said Water Supply Commission."

During the year there have been forty-two applications for charters for water or water power companies presented to the Commission, of which thirty-two have received their approval and that of the Governor.

The Legislature, by the act of June 7th, 1907, extended the jurisdiction of this Commission:

First, by requiring all applications for charters for water and water power companies to state the river, stream or other body of water, from which, and the points on same at which, it is proposed to take or use water or water power.

Second, by requiring all agreements of merger and consolidation between water companies and between water power companies, or for the purchase of the property and franchises of other water and water power companies, to designate and limit their source of supply, in the same manner as original applications for charters, and to surrender the right of eminent domain over waters, and requiring agreements for such consolidations and mergers or purchase of property and franchises, to receive the approval of this Commission.

Third, by requiring all companies subject to the provisions of the said Act to procure the approval of this Commission before they can take or use any new or additional source of supply.

In acting upon all such applications, as well as upon applications for charters, the Commission is guided by a desire to properly conserve the waters of this State, and to secure an equitable distribution thereof, in order that the public, for domestic uses, and the industries of the State for their uses, may receive the full benefit of the waters of the State.

In addition to its jurisdiction over the formation of water companies, either by their original incorporation or by consolidation, this Commission has continued, during the year, to investigate and advise itself upon the status of existing water companies, and such of the results thereof as are considered to be of interest to the public, are contained in the following pages.

In procuring the data and facts necessary to advise it of the situation with regard to the water supply of this State, and for the purpose of utilizing, conserving and equitably distributing the same, many problems have confronted the Commission. Every inhabitant and every manufacturing or industrial establishment requires water in large quantities, and in view of the constant increase in population, the necessity for water is steadily growing. Notwithstanding this, however, influences are at work which reduce the

available supply, and stream flow is becoming more irregular, many streams now carrying less water during the summer months than formerly.

In order, therefore, to properly conserve the waters of this State, this Commission has been engaged upon investigations which may improve existing conditions. The topographic and hydrographic features of the State have been carefully studied, and the result of the investigations of the Commission upon this subject are reported herein, showing the natural basins and sub-basins of the State, together with the area drained by each.

One of the causes which lessens the available water supply is deforestation, and the results of the work of this Commission show that stream flow is more irregular than formerly, and the value of the streams to the Commonwealth greatly decreased for this reason. The investigations of the Commission on this subject demonstrate that, in order to preserve the present value of our streams, active steps must be continued to protect and preserve the existing forest lands of the State, as well as to reforest those districts which have been denuded of the timber land.

The effects of floods upon the streams of this State have been given careful consideration by this Commission, and wherever possible flood conditions have been carefully studied. The control of floods is closely allied with and interdependent upon the development of water power, and the results of the investigations of this Commission on these subjects are set forth in detail in the following pages. Flood influences may be ameliorated by reforestation of the denuded forest areas of the State, by the construction of extensive storage reservoirs for excess waters, and by the straightening, widening and deepening of the channels of streams. The interest recently taken in inland navigation, to effect which would necessitate the erection of numerous dams, and the revival of the use of water as power, may aid in protecting the streams of this State against flood. Through whatever means such results are accomplished the effect will be both a decrease in the damage to property and also an increase in the available water supply. The larger streams of this State may not yet have reached the condition where conservation of the water in reservoirs for supply purposes is necessary, but provision must be made by means of reforestation and reclamation of streams which are now undesirable for use, to keep the supply at its present capacity.

The legislation of 1907, preventing the damming or obstructing of public or navigable streams without the approval of this Commission, has proved beneficial in preserving the stream flow and water supply of the State, as well as in lessening the possibility of dam-

age to property from such streams. Numerous applications have been made to this Commission under the provisions of this Act for its approval to the placing of obstructions in such streams, all of which have received careful consideration, and in some cases approval has been granted with such qualifications and under such limitations as seemed to the best interests of the State. Opportunity has also been taken by interested parties under the provisions of this Act to protest against the unlawful obstruction of streams, and in each case the protest has received the prompt attention of the Commission, with the result that unlawful and objectionable obstructions have been discontinued.

The following pages set forth the salient features of the several lines of investigation which are being carried on by the Commission. Descriptions of the principal rivers are given, with their average slope, normal, minimum and maximum flows, the uses to which the water is applied and the rainfall in the State as a whole and in each drainage basin, while the proportion and influence of forests are also considered.

Rainfall records at 185 points have been collected, checked and prepared for publication. The measurement of the discharge of streams, heretofore prosecuted by the United States Geological Survey, has been undertaken by the Commission, and a complete compilation of these records with other authentic discharge records is being prepared.

Under the provisions of the act of the Assembly of Pennsylvania, approved April 22nd, 1905, entitled, "An act to preserve the purity of the waters of the State for the protection of the public health," it is the duty of every municipal corporation, private corporation, company or individual supplying or authorized to supply water to the public within the State, to file with the Commissioner of Health a certified copy of the plans and surveys of the water works, with a description of the source from which the supply of water is derived; and no additional source of supply shall be used or new water works be constructed or extended without a written permit be obtained from the Commissioner of Health, if in his judgment the proposed source of supply appears to be not prejudical to the public health. The application for such permit must be accompanied by a certified copy of the plans and surveys for such water works, or extensions thereof, with a description of the source from which it is proposed to derive the supply; and no additional source of supply shall subsequently to be used for any such water works without a similar permit from the Commissioner of Health.

Under the provisions of said Act it is the duty of the public authorities, having by law charge of the sewer system of every municipality in this State, to file with the Commissioner of Health

a report of such sewer system, which shall comprise such facts and information as the Commissioner of Health may require, and no person, corporation or municipality shall place or permit to be placed, or discharge or permit to flow into any of the waters of the State, any sewage, except as specially provided; but the exception does not permit the discharge from any sewer system which shall be extended subsequently to the passage of the act. Wherever the general interests of the public health would be subserved thereby and upon application duly made to the Commissioner of Health by the public authorities having charge of the sewer system of any municipality, upon unanimous agreement of the Governor, Attorney General and Commissioner of Health, the said Commissioner may issue a permit for the discharge of sewage into any of the waters of the State, and may stipulate the conditions on which such discharge may be permitted.

Under this very comprehensive law, with the power it conveys to enforce penalties, etc., and with ample appropriation for a vigorous campaign against stream pollution and for the construction of proper water works, including all means and measures necessary to safe-guard the public health, such as treatment and purification plants, subsidence reservoirs, covered storage basins for ground water, etc., the State Department of Health has perfected an organization which is well equipped, and is in a comprehensive manner at work on raising the standard of water supplies and water works in the hundreds of municipalities where such systems are now installed and are in use.

This Commission has confined its labors, so far as public water supplies are concerned, to the equitable distribution of the waters, leaving the purity of the waters to be considered and conserved by the State Department of Health.

Respectfully submitted,

JOHN BIRKINBINE,
Chairman.

HENRY M. BRACKENRIDGE,
Vice Chairman.

THOMAS J. LYNCH,
Secretary.

ROBERT S. CONKLIN,
Commissioner of Forestry.

SAMUEL G. DIXON,
Commissioner of Health.

CHAPTER I.

WATER COMPANIES.

Water companies have always been considered to be public utility corporations in the highest sense of that term, for their object is to supply a necessity which every community demands, and in order to insure the public receiving this, as far as possible, and under the best conditions, water companies were given extraordinary powers. Early in the last century the legislatures incorporating water companies under special acts were inclined to give them both the right of eminent domain and the exclusive privilege of furnishing water in their respective districts, for these inducements were necessary to procure capital to supply such a vital requisite to the community. The Act of 1874, providing for the formation of corporations under a uniform law, gave to water companies, formed thereunder, both the right of eminent domain over land and materials necessary for the construction of their plants, and the exclusive privilege of supplying the district in which the company was located. This latter privilege was revoked by the Act of 1887, but the right of eminent domain over waters was conferred upon water companies by the Act of 1889.

These powers, while allowed primarily for the benefit of the public, and to insure it receiving proper service of a common necessity, became, in course of time, abused, and what was intended to operate only for the public good, in some instances was a public harm. Water franchises became a matter of traffic, and some water companies were formed with no real intention of supplying the public demands, but only to seize and hold valuable water supplies for speculative purposes, or for the private needs of individuals or corporations. This practice was followed to such an extent as seriously to endanger the continuance of an available supply of pure water for the legitimate purpose of supplying the public, and demonstrated the necessity for regulation and supervision on the part of the State, to prevent the appropriation by individuals or corporations for private or speculative purposes, under the guise of a water company charter, of rights required by the citizens of the Commonwealth. Accordingly, the Legislatures of 1905 passed two acts, one of which, approved April 13, 1905, took from water companies the right of eminent domain over waters; and the other, hereinbefore quoted, the Act of May 4, 1905, created the Water Supply Commission of Pennsylvania, whose duty is to adopt such ways and means of utilizing, conserving and distributing water supplies in such a way that the various communities of the State shall be fairly and equitably

dealt with, and providing that thereafter no water companies could be chartered without the approval of the Commission.

In considering the question of granting or withholding its approval to applications for charters, the Commission endeavors, in each case to obtain all information that can in any way guide it, by securing from the applicants all necessary maps, plans and information; also by a personal inspection of the territory to be supplied and the proposed source of supply. Particular care is taken to secure an equitable distribution of the waters of the State, and to confine their use to purposes for which they are adapted. Under the Act of 1874, and its supplements, as construed by Attorney General Carson, three classes of water companies are authorized to be created:

First, companies for the supply of water to the public, being for ordinary domestic use:

Second, companies for the supply, storage and transportation of water and water power for commercial and manufacturing purposes:

Third, companies for the storage, transportation and furnishing of water for manufacturing and other purposes, and for the creation, establishing, furnishing, transmission and use of water power therefrom.

The three classes authorized may be modified by reason of the proposed business of the corporation after its formation. Thus, under the second class, companies may be formed whose sole purpose is to supply water to manufacturing and similar establishments, or it may be the purpose of the corporation to furnish merely power. Hydro-electric companies are also authorized, under law, to develop and distribute electric power. Under the third class, a corporation may intend to supply the water for manufacturing and other purposes, or it may merely intend to supply water power. Those formed for the supply of water for manufacturing and similar purposes, or for the development of power, may use the larger streams of the State; although these, as well as the small, relatively pure streams, serve as sources of public and domestic supplies. The Commission is endeavoring to confine the companies formed for the supply of water for manufacturing and similar purposes to the largest streams, where this does not work a hardship.

The effectiveness of the legislation of 1905, creating this Commission, in remedying the evils which existed previously, may be noted in the number of water companies formed before and since its passage. Thus, as against an average of about 120 companies per year for five years preceding the passage of the Act, but 7 companies were formed during the seven months of 1905, following the creation of the commission. 30 companies were formed during the year 1906, and 32 companies during the year 1907.

Table No. 1 shows the number of companies incorporated each

year since 1816, the increase in the five years immediately prior to the passage of the Act creating the Water Supply Commission, and the decrease since that time, being apparent.

TABLE NO. 1.

Water Companies Chartered by the Commonwealth of Pennsylvania, 1816-1907.

Year.	No.	Year.	No.
1816,	2	1868,	2
1817,	2	1869,	3
1818,	1	1870,	5
1819,	1	1871,	7
1821,	2	1872,	4
1822,	1	1875,	5
1826,	2	1876,	4
1828,	1	1878,	3
1829,	1	1879,	3
1832,	1	1881,	17
1833,	1	1883,	29
1835,	1	1885,	50
1836,	3	1887,	96
1838,	3	1888,	33
1841,	2	1889,	62
1845,	2	1890,	41
1846,	3	1891,	27
1848,	2	1892,	71
1849,	3	1893,	64
1850,	5	1894,	38
1851,	4	1895,	58
1852,	2	1896,	40
1853,	3	1897,	38
1854,	7	1898,	39
1855,	3	1899,	59
1856,	4	1900,	101
1857,	3	1901,	133
1858,	4	1902,	118
1859,	7	1903,	116
1860,	3	1904,	104
1861,	1	1905,	*71
1862,	1	1905,	†7
1863,	3	1906,	30
1864,	6	1907,	32
1865,	9		
1866,	10		
1867,	5	Total,	1,616

*January to June. †June to December.

The effort of this Commission in the approval of applications for charters has been to remedy the conditions which caused the passage of the Act creating it, and its experience suggested the necessity of greater protection to the streams of the State; hence on the recommendation of the Commission, an Act was passed by the Legislature of 1907 requiring applications for charters for water companies to name the river, stream or other body of water, and the point on the same from which it is proposed to take or use water. This Act limits the right to take water from the designated river or stream only, at the designated place, and requires that any change in the source of supply shall have the approval of the Commission.

The original Act of May 4th, 1905, creating the Commission, imposed upon it the duty of approving applications for new companies, but the Act of June 7th, 1907, provides, however, that no water companies shall merge or consolidate, or purchase the property and

franchises of other water companies without the approval of the Water Supply Commission; and that the companies so merging and consolidating, or so purchasing the property and franchises of other companies, must accept the provisions of the said Act, as well as the Act of May 13th, 1905, and thereby forfeit and surrender the right of eminent domain over waters; and, further, that they shall also designate the river, stream or other body of water from which, and the point on the same at which, the water is to be taken or used, and forfeit and surrender the right to take water from any other source. This places all such companies, however old, or whatever rights they may have had, upon the same plane, with regard to their rights and powers, as companies incorporated with the approval of this Commission.

In acting upon consolidations and agreements of purchase, and also upon applications for new or additional sources of supply, the Commission is guided by the same rules and the same considerations, with regard to motives, the adaptability of the water for the purpose and to equity of distribution, as in an original application for a charter.

In addition to exercising its jurisdiction over the formation of water companies in the manner pointed out, the Commission has also, where possible, determined the status of all water companies theretofore created, procured definite data as to their sources of supply, the points of distribution and the use to which the water is put, and ascertained whether the company is or is not in operation and exercising its public franchises.

To show the extent to which water is furnished to communities in Pennsylvania, and the relation between the number of supplies owned by companies and by municipalities, the following statistics have been prepared:

In 1900 the population of Pennsylvania was, as determined by the United States Census, 6,302,115, while the estimate of that Bureau for 1905, was 6,824,115, showing a growth at the rate of 1.6 per cent. per year. Of the population in 1900, 3,448,610, or 54.7 per cent., lived in cities or towns of 2,500 population or over, and 2,853,505, or 45.3 per cent., in smaller towns or country districts. Of the total population fully 60 per cent., therefore, receives a water supply through some general system.

Table No. 2 presents the percentage of the population residing in cities and towns of 2,500 inhabitants or more, divided according to size of community.

TABLE NO. 2.

Percentage of Population of Pennsylvania Residing in Cities and Towns of Various Sizes.

Percentage of population of State.	Actual population 1900.	Live in cities of population of
29.3	1,847,235	Over 100,000.
9.8	569,623	25,000 to 100,000
7.1	449,079	8,000 to 25,000
5.7	357,400	4,000 to 8,000
3.6	225,273	2,500 to 4,000
54.7	3,448,610	

Table No. 3 indicates the ownership of water supplies according to population of municipalities:

TABLE NO. 3.

Municipal and Private Company Supplies to Large Cities and Boroughs of Pennsylvania, 1900.

Population.	Number of municipalities.	Number supplied by municipality.	Number supplied by water companies.
Over 100,000	4	3	*2
Between 25,000 and 100,000,	14	7	7
Between 15,000 and 25,000,	7	1	6
Between 8,000 and 15,000,	29	13	16
Between 4,000 and 8,000,	65	10	55
Between 2,500 and 4,000,	71	13	58
	190	*47	*144

*One city supplied by both private and municipal systems.

This table shows that of the municipalities having a population of more than 2,500, three are supplied by incorporated water companies to one supplied by municipally owned plants. These figures include only 190 of nearly 1,000 districts supplied, and among the supplies for towns smaller than 2,500 population, the proportion of private to municipal plants is much greater.

So far as our investigations have proceeded, we have no report of a town of over 1,500 inhabitants without some form of water system, while several with populations as small as 200 are so supplied. A population of 400 to 500 seems generally to be the limiting figure, but some towns and boroughs of over 1,000 population are not being supplied by any general system of water works.

The Act approved May 28th, 1907, provides that a water company obtaining its supply from within a municipality shall furnish water to inhabitants thereof, or forfeit its right to such a quantity of water as will supply the needs of the inhabitants. Under this Act three proceedings have been instituted before the Water Supply Commission. In one case the water company immediately agreed to extend its lines into the territory from which the petition came, while in the other two cases amicable adjustments were arrived at.

Of the water companies chartered in this State since 1816 many are not in existence, and the reason for this is two-fold. First, a number of companies, particularly those formed for speculative purposes, have failed to comply with the law in regard to doing work within the time limit authorized by their charters, and their franchises have, therefore, reverted to the Commonwealth; and second, many corporations have either merged and consolidated their rights and franchises with and into those of other companies, forming one corporation in the place of two or more theretofore existing, or the same result has been obtained by the purchase by one company of the property and franchises of one or more other companies, in which case the companies so purchased cease to exist as individual companies. While, however, the actual number of water companies in existence is much less than the number formed, the area of territory supplied with water is not proportionately reduced for the reason that where a consolidation is made the same territory formerly supplied by two or more companies is supplied by one company.

In addition to the consolidations, combinations are practically effected by the purchase by one company of the stock of others. Records of such transactions are not required to be filed with this Commission, or in any other public office, and the number of such concerns allied by stock ownership can, therefore, only be approximated. While it was the aim of the Act of June 7th, 1907, to bring within the control of the Water Supply Commission companies formed before its creation, by requiring such companies to procure the approval of the Commission before a merger and consolidation, or before the purchase of the property and franchises of another company, practical consolidations have been formed by the purchase by one company of the capital stock of other companies without the approval or control of the Commission. It would seem, therefore, advisable, in order to effect a more complete supervision of water companies by this Commission, that provision should be made for subjecting such companies to its control, and for the forfeiting of the right of eminent domain by water companies desiring to own or control other water companies by virtue of an ownership of their capital stock.

CHAPTER II.

OBSTRUCTIONS TO STREAMS.

Prior to the passage of the Act of May 28th, 1907, no legislation specifically prevented, or imposed conditions upon the obstruction of streams of this State by dams or otherwise. Now, however, no obstruction can be placed legally in or along any public or navigable stream which had heretofore been declared a public highway without the approval of this Commission. This Act has met with much approbation and opportunity has been taken under it to protest against types of obstructions to the streams which are considered detrimental but which have heretofore been allowed to be erected without objection.

Before the passage of this act it had been the custom, in many instances, for railroad companies, whose lines lie along large rivers, to make fills beyond the existing banks thereof for the purpose of obtaining additional track facilities. Since the passage of this act such companies have been required to obtain the permission of this Commission before such fills can be made.

Many applications for permission to place obstructions in or along streams of the State by means of dams, wing-walls or abutments in the shape of fills to existing banks have been made to this Commission, as have also protests by interested parties against the placing of obstructions in such streams.

In acting upon applications and protests of this kind we have been guided by considerations of stream capacity with a view both to preserve the present volume of water in the stream and to prevent increased possibilities of flood.

Applications involving the erection of structures not liable to do damage to the stream or the property along its banks have been approved subject to such modifications as it has been deemed necessary by this Commission to impose. Protests have received equally careful attention and where upon examination it has appeared that the protest was well founded, a discontinuance of the obstruction has been effected or sufficient modifications required to answer all practical purposes.

The investigations under this act have brought to light the existence of some serious conditions, of which the following are instances. The carrying capacity of the Kiskiminetas river has been greatly reduced by the flattening of the slope by deposits carried down from above, and by encroachments along its banks, while changing conditions in its water shed make necesasry a greater

PLATE 1.

Typical encroachment by refuse deposit—Susquehanna River near Columbia.

PLATE 2.

Showing contraction of flood channel of Turtle Creek by stone arch bridge.

facility for discharge. This stream was one of the chief contributors of the great flood at Pittsburg in March, 1907.

From investigations which were made in response to an application from the citizens of Turtle Creek borough a serious condition was found to exist in Turtle creek, in Allegheny and Westmoreland counties, owing to the reduction in the size of its channel by encroachments and by deposits. Further obstructions which were in process of erection at the time of our investigation have been discontinued. A thorough study is now being made to determine the cause as well as the effects of the numerous disastrous floods occurring in the valley of this stream with a view of suggesting remedies therefor.

CHAPTER III.

HYDROGRAPHIC FEATURES OF PENNSYLVANIA.

Pennsylvania is nearly a rectangle in shape, enclosing a gross area of 45,126 square miles, of which 294 square miles are covered by water.

The State is divided topographically and hydrographically into a number of drainage basins and sub-basins, defined by prominent physical features, presenting in its water sheds the divides between the Atlantic Ocean, Gulf of Mexico and the Great Lakes drainage systems. Rain falling in Pennsylvania finds its way into the Atlantic ocean by the Delaware, Susquehanna and Potomac rivers, through Delaware and Chesapeake bays. By the Allegheny and Monongahela rivers, water flows into the Ohio river, thence into the Mississippi river and the Gulf of Mexico. Other streams discharge into Lake Erie and Lake Ontario, thence into the St. Lawrence river through the Gulf of St. Lawrence into the Atlantic ocean.

The State has three important river systems,—the Delaware in the east, the Susquehanna in the centre and the Ohio in the West; while smaller areas drain into the Potomac river in the south-central, into Lake Erie in the northwest, and into Lake Ontario, through the Genesee river, in the north-central section.

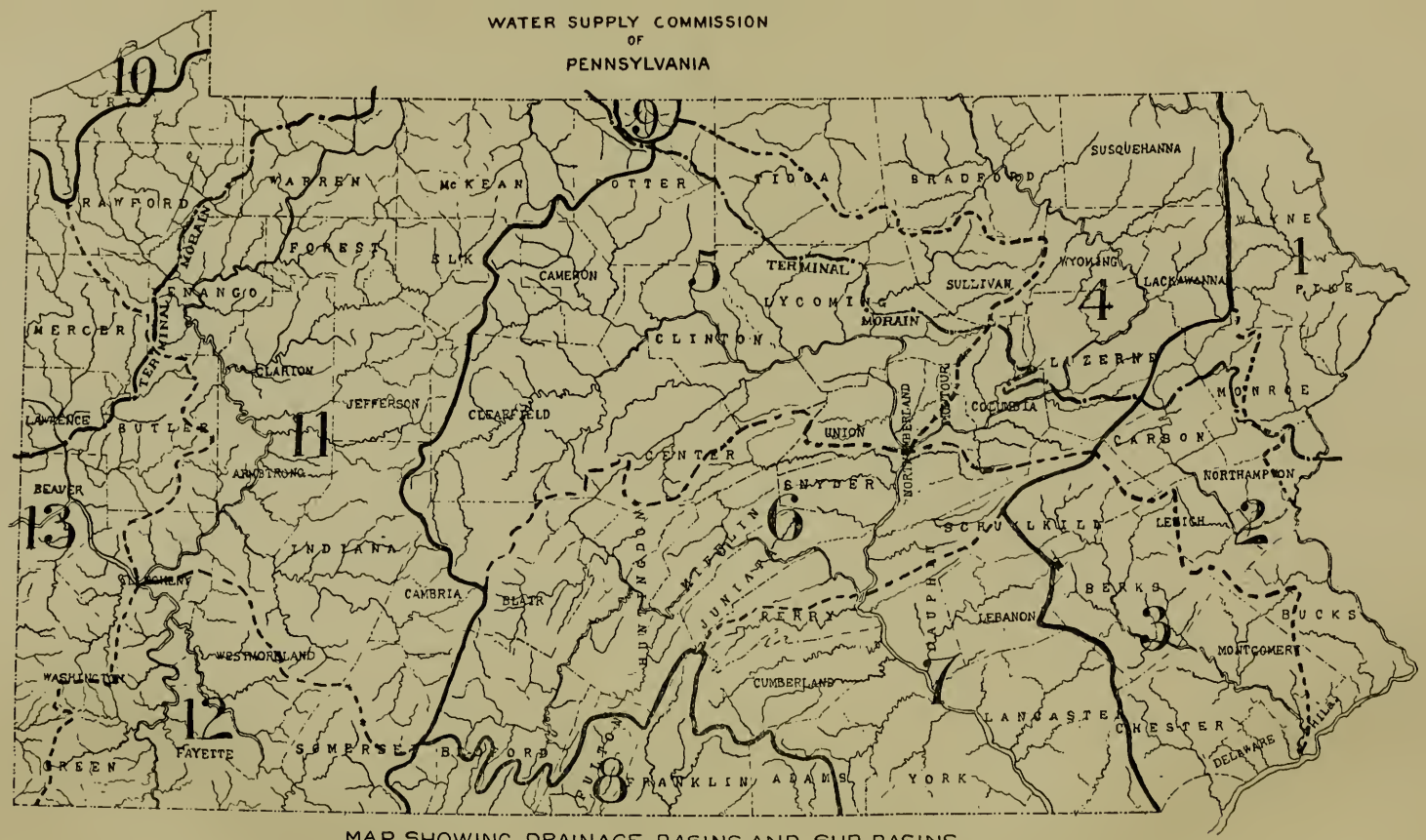
The Water Supply Commission has considered the State as separated naturally into six primary drainage basins.

1. Delaware Basin.
2. Susquehanna Basin.
3. Ohio Basin.
4. Potomac Basin.
5. Lake Erie Basin.
6. Genessee Basin.

The first three are further divided into sub-basins as follows:

The Delaware Basin into the
- Lower Delaware Sub-basin,
- Middle Delaware Sub-basin,
- Upper Delaware Sub-station.

The Susquehanna Basin into the
- Lower Susquehanna Sub-basin,
- Middle Susquehanna Sub-basin,
- North Branch Sub-basin.
- West Branch Sub-basin.



MAP SHOWING DRAINAGE BASINS AND SUB-BASINS

DELAWARE BASIN	1. UPPER 2. MIDDLE 3. LOWER	SUSQUEHANNA BASIN	4. NORTH BRANCH 5. WEST "	OHIO BASIN	11. ALLEGHENY 12. MONONGAHELA 13. OHIO
	8. POTOMAC		6. MIDDLE 7. LOWER 9. GENESEE		10. LAKE ERIE

PLATE 3.

The Ohio Basin into the
Ohio Sub-basin,
Allegheny Sub-basin,
Monongahela Sub-basin.

The Delaware Basin occupies the eastern portion of the State and includes all the territory in Pennsylvania draining into the Delaware river. The Lower Delaware Sub-basin embraces the portion above the Pennsylvania-Delaware line to and including the port of Philadelphia and the Schuylkill river, covering all of Delaware county and portions of Schuylkill, Lehigh, Berks, Lebanon, Montgomery, Chester, Bucks and Philadelphia counties. The Middle Delaware Sub-basin extends from Philadelphia to Easton, including the Lehigh river, and covers almost all of Carbon county and portions of Lackawanna, Luzerne, Monroe, Schuylkill, Northampton, Lehigh, Berks, Bucks, Montgomery and Philadelphia counties. The Upper Delaware Sub-basin includes all the area in Pennsylvania tributary to the Delaware above Easton, including all of Pike county and parts of Wayne, Monroe, Northampton and Lackawanna counties.

The Susquehanna Basin occupies the central portion of the State and includes all the territory in Pennsylvania draining into the Susquehanna river. The Lower Susquehanna Sub-basin covers the portion above the Pennsylvania-Maryland line and below the mouth of the Juniata river, embracing parts of Schuylkill, Berks, Cumberland, Lebanon, Dauphin, Chester, York, Adams, Lancaster, Franklin and Perry counties. The Middle Susquehanna Sub-basin includes the area between the mouth of the Juniata river and the forks at Northumberland, including the Juniata river covering all of Blair, Snyder, Juniata, Mifflin and Huntingdon counties, and parts of Centre, Union, Northumberland, Schuylkill, Dauphin, Perry, Franklin, Fulton, Bedford and Somerset counties. The North Branch Sub-basin includes all that part of the Susquehanna Basin tributary to the North Branch, and the West Branch Sub-basin all the area tributary to the West Branch of the Susquehanna river; the former covering all of Susquehanna and almost all of Wyoming counties, together with portions of Potter, Tioga, Bradford, Sullivan, Lycoming, Wayne, Lackawanna, Luzerne, Columbia, Schuylkill, Montour, Carbon and Northumberland counties; and the latter all of Cameron and Clinton counties, and parts of Potter, Jefferson, McKean, Elk, Clearfield, Indiana, Cambria, Centre, Lycoming, Sullivan, Bradford, Wyoming, Columbia, Montour, Northumberland and Union counties.

The Ohio Basin occupies the western section of the State and includes the area in Pennsylvania tributary to the Ohio river and its main affluents, the Allegheny and Monongahela rivers. The Alle-

gheny Sub-basin embraces the area draining into the Allegheny river and covers all of Armstrong, Clarion, Forest and Warren counties, and parts of Potter, McKean, Elk, Clearfield, Jefferson, Indiana, Cambria, Westmoreland, Somerset, Allegheny, Butler, Venango, Crawford, Erie and Mercer counties. The Monongahela Sub-basin includes the area draining into the Monongahela river, and covers all of Fayette county and parts of Westmoreland, Somerset, Greene, Washington and Allegheny counties. The Ohio Sub-basin covers the area tributary to the Ohio river proper, below the junction of the Allegheny and Monongahela rivers, including the Beaver river, and includes all of Lawrence and Beaver counties and parts of Crawford, Mercer, Venango, Butler, Allegheny, Washington and Greene counties.

Along the southern boundary of Pennsylvania a considerable area, including portions of Adams, Franklin, Bedford, Somerset and York counties, drains into the Potomac river through Wills, Little Antietam, Conococheage, Licking and other creeks. This is considered the Potomac Basin.

In the northwestern corner of the State a relatively small area, covering portions of Erie and Crawford counties, drains into Lake Erie through Elk, Conneaut and other creeks. This is designated the Lake Erie Basin.

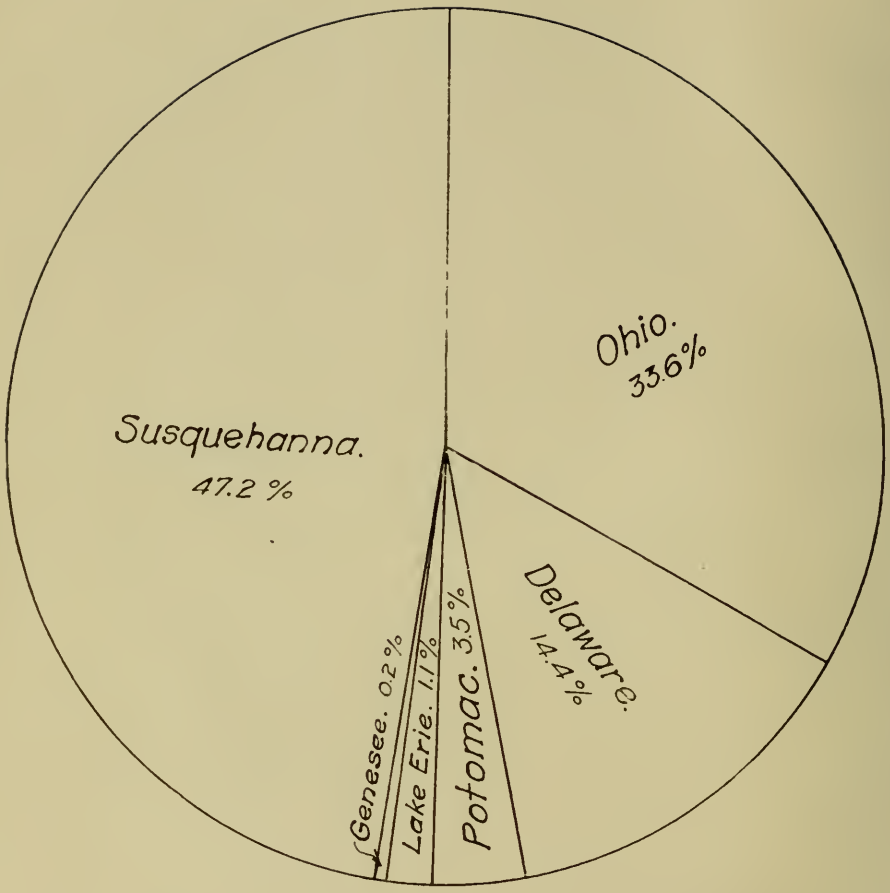
In the north-central portion of the State a small area in Potter county drains northward, through the Genessee river, into Lake Ontario, forming the Genessee Basin.

The areas in Pennsylvania of the various basins and sub-basins enumerated, computed as closely as possible from the data available, are shown in the following tables:

TABLE NO. 4.

Areas of Primary Drainage Basins.

Basin.	Area in Pennsylvania in square miles.	Percentage of total area of State.
Delaware,	6,520	14.4
Susquehanna,	21,320	47.2
Ohio,	15,149	33.6
Potomac,	1,555	3.5
Lake Erie,	490	1.1
Genessee,	92	0.2
Total,	45,126	100.0



Proportional Part of Pennsylvania
occupied by
Each Drainage Basin.

Total Area of State, 45,126 sq. miles.

PLATE 4.

TABLE NO. 5.

Areas of Sub-Drainage Basins.

Sub-basin.	Area in square miles.	Percentage of Primary Basin.
Lower Delaware,	2,564	39.3
Middle Delaware,	2,065	31.7
Upper Delaware,	1,891	29.0
Lower Susquehanna,	4,075	19.1
Middle Susquehanna,	4,965	23.3
North Branch,	5,215	24.5
West Branch,	7,065	33.1
Ohio,	3,115	20.6
Allegheny,	9,310	61.5
Monongahela,	2,724	17.9
Total,	42,989	100.00

Table No. 4 indicates that the Delaware, Susquehanna and Ohio rivers, with their tributaries, drain 95.2 per cent. of the State. Figure No. 6 illustrates Table No. 4 in diagramatic form, the area of the entire circle representing the area of the Commonwealth, while the several sectors enclose areas proportional to the percentages of the area of the State covered by each drainage basin.

As portions of the total drainage areas of the main rivers are in adjacent States, Tables No. 6, 7 and 8 were prepared to illustrate this fact; all of the areas being considered as parts of the total basin above the points where the rivers leave the State of Pennsylvania.

TABLE NO. 6.

Constituent Parts of Delaware Basin Above Pennsylvania-Delaware State Line.

	Area in square miles.	Per cent. of area of basin.
In Pennsylvania,	6,520	59.8
In New Jersey,	1,800	16.5
In New York,	2,580	23.7
Total area tributary to Delaware River,	10,900	100.00

TABLE NO. 7.

Constituent Parts of Susquehanna Basin Above Pennsylvania-Maryland State Line.

	Area in square miles.	Per cent. of area of basin.
In New York on North Branch,	6,270	22.8
In Pennsylvania, total,	21,320	77.2
Total area tributary to Susquehanna river,	27,590	100.0

TABLE NO. 8.

Constituent Parts of the Ohio Basin Above Pennsylvania-Ohio State Line.

	Area in square miles.	Per cent. of area of basin.
Area of Allegheny river drainage in New York,	1,850	8.6
Area of Monongahela river drainage in West Virginia and Maryland,	4,605	21.3
Ohio, Allegheny and Monongahela in Penna.,	15,149	70.1
Total area tributary to Ohio river,	21,604	100.0

PROMINENT FEATURES OF THE PRINCIPAL RIVERS.

Descriptions of the principal rivers are presented below, their flood conditions being detailed in Chapter No. 6.

DELAWARE RIVER.

Two branches of the Delaware river, the east and the west, have their sources in the Catskill mountains of south-western New York, at an elevation of 1,900 feet above sea level, and flow south-westerly, uniting at Hancock, New York, at the New York-Pennsylvania boundary line, at an elevation of approximately 920 feet above sea level, from which point a generally southerly course is continued to its mouth in Delaware bay, 60 miles below Philadelphia. The Delaware river forms the boundary between New York and Pennsylva-

nia from Hancock to Port Jervis, New York, a distance of approximately 100 miles; then the boundary between Pennsylvania and New Jersey for about 170 miles, and finally the boundary between Delaware and New Jersey down to its mouth in Delaware bay.

Below Hancock the principal tributaries from Pennsylvania are the Lackawaxen, Lehigh and Schuylkill rivers, and Broadhead, Neshaminy and Brandywine creeks. From New York comes Neversink river, and from New Jersey the Flat Brook, Paulins Kill, Pequest, Lopatcong, Pohatcong and Musconetcong rivers.

The total length of the Delaware river is approximately 410 miles, its drainage basin in Pennsylvania is 6,520 square miles, being 14.4 per cent. of the area of the State, and 60 per cent. of the entire Delaware river drainage basin above the Pennsylvania-Delaware State line. The river is flanked by hills in its upper reaches, cuts through the Kittatinny mountains, at Delaware Water Gap, and continues as a broad stream below. Tide-water extends to Trenton, 50 miles above the Pennsylvania-Delaware State line, to which point the river is navigable, while from Bristol to Easton it has been canalized. Navigation on the Schuylkill river from Philadelphia to Port Carbon, and on the Lehigh river from its mouth to Mauch Chunk, has been improved by means of canals and slackwater pools. Navigation for ocean-going vessels extends to Philadelphia, the Federal, State and City Governments having spent approximately $7,000,000 in dredging a 30 foot channel up to Philadelphia, and in deepening the Schuylkill river through that city. On the New Jersey side of the river and in that state are the Morris and the Delaware and Raritan canals, the former extending from Jersey City, through Newark, Paterson and Dover, to the Delaware river at Phillipsburg, opposite Easton. The Delaware and Raritan canal extends from the Raritan river at New Brunswick to the Delaware river at Bordentown, New Jersey. A feeder, which is also navigable, runs from the main canal at Trenton to the Delaware river at Bull's Island.

The upper portion of the Delaware river drains a region abounding in lakes and ponds, where a limited amount of the original forest cover still remains, the tributaries from this section being comparatively regular in flow. In the Middle and Lower Sub-basins the streams are more flashy, the country being largely deforested, cultivated and thickly inhabited.

A few miles below Trenton the stream crosses the edge of the Piedmont Plateau, producing a fall of about 8 feet. Above this point the general slope of the stream is 3.5 feet per mile to Port Jervis, broken by a succession of rapids with intervals of slack water between. Above Port Jervis the fall is more rapid, averaging 6 feet per mile, to the northern line of the State.

Water power is little developed on the main stream, due largely to its inter-state character and the resulting legal difficulties in using the stream for power purposes. The Schuylkill, Lackawaxen, Lehigh and the smaller tributaries, afford opportunities for the generation of water power, some of which have been developed.

On the banks of the Delaware river are located Port Jervis, N. Y., Easton, Bristol, Philadelphia and Chester, Pennsylvania; and Belvidere, Phillipsburg, Lambertville, Trenton, Bordentown, Burlington and Camden, New Jersey; while on the tributary streams in Pennsylvania lie Bethlehem, South Bethlehem, Allentown, Mauch Chunk, Conshohocken, Norristown, Phoenixville, Pottstown, Reading, Pottsville, Hazleton, Ashland and others. Its basin is gridironed by numerous branch lines of the Pennsylvania Railroad, the Delaware, Lackawanna and Western, the Philadelphia and Reading, the Central of New Jersey, the Lehigh Valley, the New York Central and the Erie railroads.

This basin is subject to an average rainfall of 46.1 inches annually, a greater precipitation than in any other portion of the State.

The average discharge of the Delaware river at Lambertville, N. J., at which point its flow has been measured by the United States Geological Survey since 1897, is reported as 14,150 cubic feet per second, or 2.07 cubic feet per second per square mile of drainage area. The maximum authentic recorded flow was during the flood of October, 1903, when a discharge of 250,000 cubic feet per second, or 36.5 cubic feet per second per square mile was reached. The lowest discharge recorded at Lambertville is 1,200 cubic feet per second, or 0.175 cubic feet per second per square mile, exceeding on this basis the dry weather flow of any other large river in the State, with the exception of the Allegheny river at Kittanning, where, however, the record is short.

TABLE NO. 9.

Principal Streams of Delaware Basin.

Name of Stream.	Approximate drainage area in square miles.	Tributary from
Delaware river,	*10,900	Pa., N. Y. and N. J.
West Branch of Delaware river,	350	N. Y.
East Branch of Delaware river,	920	N. Y.
Lackawaxen river,	600	Penna.
Wallenpaupack creek,	235	Penna.
Mongaup creek,	230	N. Y.
Neversink river,	345	N. Y.
Broadhead creek,	290	Penna.
Paulins Kill,	180	N. J.
Pequest river,	160	N. J.
Lehigh river,	1,330	Penna.
Musconetong river,	150	N. J.
Neshaminy creek,	230	Penna.
Rancocas creek,	340	N. J.
Schuylkill river,	1,915	Penna.
Little Schuylkill river,	135	Penna.
Perkiomen creek,	360	Penna.
Maiden creek,	217	Penna.
Tulpehocken creek,	215	Penna.
Brandywine creek,	565	Pa. and Del.

*Above Pennsylvania-Delaware line.

SUSQUEHANNA RIVER.

The Susquehanna river, the largest stream in the State, is formed by the junction of the North and West Branches at Northumberland, Northumberland county, Pennsylvania. The North Branch, together with the section below the junction of the two branches, is now recognized as the Susquehanna river, but for convenience the old nomenclature has been retained.

From Northumberland the river follows a nearly southerly course to its junction with the Juniata river, near Duncannon, Perry county, at which point it cuts through the North mountain, turning to the southeast, and continuing this course to its mouth in Chesapeake bay, at Havre de Grace, Md. From Northumberland to a point about 12 miles below Columbia the river is wide and shallow, averaging about one mile in width, with a slope of 2.6 feet per mile, breaking through a series of parallel ridges in the upper portion, and crossing the Cumberland Valley in the lower portion. About 23 miles above the Maryland-Pennsylvania State line the stream enters a gorge where it crosses the Piedmont Plateau and becomes a more narrow and rapid stream, with an average fall of 6.1 feet per mile, continuing this character until it leaves the State.

The prominent tributaries are the West Branch and the North Branch, Juniata river, and Penns, Sherman, Conodoguinet, Swatara, Conestoga, Pequea, Conewaga, Codorus and Octorara creeks.

The total length of the Susquehanna river from Northumberland to the State boundary is 110 miles. The drainage basin of the stream in Pennsylvania is approximately 21,320 square miles, or 47.2 per cent. of the entire area of the State, while the total area tributary at the Pennsylvania-Maryland state line is approximately 27,590 square miles.

The Susquehanna river is not navigable except locally for small flat bottom boats adaptable for local trade and pleasure, and this only during certain seasons of the year. Canals formerly followed its banks and those of the North and West Branches, Juniata river, and Swatara creek, but they are now abandoned. This entire basin is largely deforested, but it is to some extent in process of regrowth. The streams are subject to sudden rises and to extremely low summer flow. There are few natural lakes or ponds in the Middle and Lower Susquehanna Sub-basins.

The nearly uniform slope which exists from Northumberland to York Haven is broken at the latter point by rapids, and again in the gorge below Columbia. The water power on this stream at present is developed only at York Haven, but large installations are in progress of construction on the main stream and on the Juniata river, while smaller powers have been utilized upon important tributaries.

The chief municipalities on the main river and its tributaries below Northumberland are Sunbury, Altoona, Hollidaysburg, Tyrone, Huntingdon, Lewistown, Harrisburg, Shamokin, Shenandoah, Lebanon, York, Lancaster and Columbia. The main river, both branches and many of its tributaries are followed by the Pennsylvania Railroad or the Philadelphia and Reading Railroad.

The average annual rainfall over the entire Susquehanna Basin in Pennsylvania is 41.0 inches.

The flow of the Susquehanna river is being measured at Harrisburg and McCall Ferry, and its branches at Wilkes-Barre and Danville on the North Branch, at Williamsport on the West Branch and at Newport on the Juniata river. During the sixteen years of recorded flow at Harrisburg the average discharge has been 38,359 cubic feet per second, or 1.6 cubic feet per second per square mile; the maximum, which occurred during the flood of 1889, estimated on the basis of subsequent measurements, was 700,000 cubic feet per second, or 29.2 cubic feet per second per square mile; while the minimum was 2,330 cubic feet per second, or 0.098 cubic feet per second per square mile.

NORTH BRANCH SUSQUEHANNA RIVER.

The North Branch rises in the Catskill mountains, in southeastern New York, close to the headwaters of the Delaware river, draining 6,270 square miles in that State, flows in a generally southwesterly course, crossing into Pennsylvania near Sayre, Brad-

ford county, then following a southeasterly course to Wilkes-Barre, and then a southwesterly course to its junction with the West Branch at Northumberland, Pa.

The principal tributaries in New York are the Chenango and Unadilla rivers, and in Pennsylvania the Chemung and Lackawanna rivers, Tunkhannock and Fishing creeks.

The total length of the North Branch, from Northumberland, Pa., to the forks at Oneonta, New York, is about 290 miles, and its total drainage area is 11,485 square miles, of which 6,270 square miles are in New York. From Wilkes-Barre northward the sub-basin abounds in lakes and ponds, and the tributaries are less flashy in character than those in the southern section. The part of the sub-basin in Pennsylvania has been practically stripped of its forest growth, although in some sections regrowth is in process. In the southern section many streams have been greatly injured by mine wastes from the anthracite coal fields, and by mill refuse.

The slope of the North Branch is quite uniform from the New York-Pennsylvania state line to Northumberland, unbroken by falls or rapids of magnitude, the average fall being at the rate of two feet per mile. Navigation is impossible except locally for small boats.

Practically no water power is developed on the North Branch in Pennsylvania, the small fall, wide valley and proximity of coal being the cause; but small powers are located on some tributaries.

The principal municipalities on the North Branch sub-basin are Binghampton, Owego and Elmira, New York; and Sayre, Tunkhannock, Carbondale, Scranton, Pittston, Wilkes-Barre, Plymouth, Nanticoke, Bloomsburg and Danville in Pennsylvania. The railroads traversing this sub-basin are the Pennsylvania, the Delaware, Lackawanna and Western, the Delaware and Hudson, New York Central and Hudson river, the Erie, and the Philadelphia and Reading railroads.

The average discharge of the North Branch at Danville, recorded since 1899, has been 17,990 cubic feet per second, or 1.6 cubic feet per second per square mile. The maximum, in March 1902, was 304,000 cubic feet per second, or 27.5 cubic feet per second per square mile. The minimum flow, in September, 1900, was 822 cubic feet per second, or 0.074 cubic feet per second per square mile.

WEST BRANCH SUSQUEHANNA RIVER.

The West Branch rises in Carroll Township, Cambria county, Pennsylvania, at an elevation of 2,100 feet above sea level, flows in a northeasterly direction to Keating, Clinton county, and then in a general southeasterly direction to its mouth, at Northumberland. Rising on the west slope of the Allegheny mountains, it cuts through

the range and drains the eastern slope. It is a mountain stream for 91 miles, between Curwensville, Clearfield county, and Queens Run, Clinton county, having a slope of 6.2 feet per mile; and is a broad shallow river in its lower course, where for 69 miles, between Queens Run and its junction with the North Branch, the fall is at the rate of 2 feet per mile. The total length of the river is approximately 240 miles and its drainage basin 7,065 square miles.

Except in its extreme northern section, where a large part of the merchantable timber in the State of Pennsylvania remains, this drainage basin has been denuded of forests, and in the extreme southwestern corner many streams have been injured by mine wastes from the bituminous coal fields in Cambria and Clearfield counties. In Centre county many tributaries are fed by large limestone springs, which aid in maintaining a strong flow during dry weather. The remaining streams in this sub-basin are of a flashy character, and there are practically no natural lakes or ponds to influence the discharge. The principal tributaries are Sinnemahoning, Clearfield, Moshannon, Bald Eagle, Pine, Loyalsock and Lycoming creeks. The prominent municipalities on the sub-basin are Curwensville, Clearfield, Bellefonte, Lock Haven, Williamsport and Lewisburg. The stream and most of the important tributaries are paralleled by either the Pennsylvania, the New York Central and Hudson River, or the Philadelphia and Reading railroads.

The West Branch of the Susquehanna river has a uniform profile from Lock Haven to Northumberland, the grade being slight and the current sluggish. Above Lock Haven the stream has a more rapid slope. Practically no water power is developed on the main streams, but some of the tributaries are used, to a limited extent, for this purpose.

The maximum flow of the West Branch, recorded at Williamsport since 1895, was 164,100 cubic feet per second, or 29 cubic feet per second per square mile, in March 1902. The average discharge during the same period was 9,130 cubic feet per second, or 1.6 cubic feet per second per square mile, and the minimum discharge in 1895 was 410 cubic feet per second, or 0.072 cubic feet per second per square mile.

PLATE 5.
West Branch of Susquehanna River at Williamsport.

PLATE 6.

Junction of Allegheny, Monongahela and Ohio Rivers at Pittsburg, Penna.

TABLE NO. 10.

Principal Streams in Susquehanna Basin.

Name of Stream.	Approximate drainage area in square miles.	Tributary from
Susquehanna river,	*27,590	N. Y. and Pa.
North branch of Susquehanna river,	11,485	.....
Unadilla river,	560	N. Y.
Chemung river,	2,520	N. Y.
Chenango river,	1,580	N. Y. and Pa.
Towanda creek,	220	Penna.
Wyalusing creek,	205	Penna.
Tunkhannock creek,	410	Penna.
Lackawanna river,	325	Penna.
Fishing creek,	355	Penna.
West branch of Susquehanna river,	7,065	.....
Moshannon creek,	235	Penna.
Clearfield creek,	340	Penna.
Sinnemahoning creek,	960	Penna.
Bald Eagle creek,	725	Penna.
Pine creek,	930	Penna.
Loyalsock creek,	495	Penna.
Lycoming creek,	260	Penna.
Penns creek,	360	Penna.
Juniata river,	3,530	Penna.
Frankstown branch,	935	Penna.
Little Juniata river,	325	Penna.
Raystown branch,	910	Penna.
Tuscarora creek,	250	Penna.
Shermans creek,	246	Penna.
Conodoguinet creek,	481	Penna.
Yellow Breeches creek,	225	Penna.
Swatara creek,	535	Penna.
Conewago creek,	507	Penna.
Codorus creek,	268	Penna.
Conestoga creek,	434	Penna.
Octoraro creek,	216	Pa. and Md.

*Above the Pennsylvania-Maryland State line.

OHIO RIVER.

The Ohio river, the second largest stream in the Commonwealth, formed by the junction of the Allegheny and the Monongahela rivers at Pittsburg, follows a general northwesterly course to the Ohio-Pennsylvania state line, a distance of 39.4 miles. Its chief tributaries in this stretch are the Beaver river, entering from the north at Rochester, Beaver county, Little Beaver river, from the north at the State line, and Racoon creek flowing from the south.

The drainage area of the Ohio River Sub-basin is 3,115 square miles, but the area in Pennsylvania draining into the Ohio, including the Allegheny and Monongahela rivers, is 15,149 square miles, or 33.6 per cent. of the area of the State. The total drainage area tributary to the Ohio river through Pennsylvania, including the entire drainage basins of the Allegheny and Monongahela rivers in New York and West Virginia, is 21,604 square miles.

The Ohio river in Pennsylvania is a broad, shallow stream flowing between hills of considerable magnitude. Its slight slope, averaging from Pittsburg to the State line 1.2 feet per mile, favors its

improvement for navigation by means of a series of dams and locks, which is now in progress under the direction of the United States government. The Ohio river to its confluence with the Mississippi river at Cairo, Ill., is extensively used for the transportation of fleets of coal barges; but until the improvements to navigation are completed through navigation will be limited to periods of comparatively high water.

The Beaver Division of the Pennsylvania Canal followed the Beaver river from its mouth, up that stream and the Shenango river, by means of slack water pools. An extension to Lake Erie was begun but never completed. A company has been incorporated for the construction of a ship canal from Pittsburg along the north bank of the Ohio river, and thence up the Beaver and Mahoning rivers, eventually reaching Lake Erie, at Astabula, Ohio, over a portion of the route of the old canal.

The upper tributaries of the Beaver river rise in a country abounding in lakes, ponds and swamps and are not subject to sudden floods or to extremely low flow in dry weather. The tributaries from the south are of a more torrential character.

No water power is developed on the Ohio river, but about 3,000 horse power is derived from the Beaver river near its mouth, by means of a series of dams between Beaver Falls and Rochester, where the river has a fall of 52 feet in five and one-half miles.

The principal towns on the Ohio river and its tributaries in Pennsylvania, exclusive of the Allegheny and Monongahela rivers, are Allegheny, Rochester, Beaver Falls, New Castle, Sharon, Butler, Washington, Carnegie and South Pittsburg. The banks are lined with suburban settlements and manufacturing plants. The Pennsylvania, the Baltimore and Ohio, and the Pittsburgh and Lake Erie Railroad systems traverse this sub-basin.

No discharge measuring station is maintained on the Ohio river between Pittsburg and the State line. The average discharge of the Ohio river at Wheeling, W. Va., 50 miles below the State line, as recorded by the United States Geological Survey for 1905-06, is 40,400 cubic feet per second, or 1.7 cubic feet per second per square mile. The maximum during the flood of February, 1884, was 473,400 cubic feet per second, or 20 cubic feet per second per square mile. The flood of March, 1907, discharged 440,000 cubic feet per second. The minimum flow was approximately 2,500 cubic feet per second, or 0.105 cubic feet per second per square mile. The average rainfall over the Ohio Sub-basin is 37.7 inches per year.

ALLEGHENY RIVER.

The Allegheny river, the largest tributary of the Ohio river, rises in Potter county, Pennsylvania, on the western slope of the Alle-

gheny mountains, at an elevation of about 2,250 feet above sea level, and flows northwesterly into New York, where, at Salamanca, Cattaraugus county, it swings to the southwest; continuing this course, back into Pennsylvania, to Franklin, Venango county, from which point it follows a southeasterly and then a southwesterly course to Pittsburg. Its course in New York is through a wide valley and on a flat grade. Coming back into Pennsylvania the hills converge and the valleys narrow. In its lower section it is a wide, shallow river, with a slope averaging from Oil City to Pittsburg 2.1 feet per mile, broken by a series of riffles and pools. The lower portion of the river continues among hills, and is normally between 1,000 and 1,100 feet wide. Between Oil City, Venango county, and Tarentum, Allegheny county, the narrowest portion of the river is about 480 feet wide and the widest 2,140 feet. The lower portion of the river valley is thickly inhabited and its shores are bordered with coal mines, steel works, blast furnaces, factories, and other industrial settlements. The principal tributaries are Conewango creek, Tionesta creek, Oil creek, French creek, Clarion river, Red Bank creek, Mahoning creek and Kiskiminetas river.

The total length of the Allegheny river from Port Allegheny to Pittsburg, is about 280 miles, and its drainage area is about 11,140 square miles, of which 9,310 square miles, or 20.6 per cent. of the area of the State, is in Pennsylvania.

The river was formerly much used for the transportation of logs, but with the destruction of the forests this industry has practically ceased. At one time the Allegheny was navigable for steamboats up to Warren, Warren county, but for many years the traffic has been discontinued. The United States Government is improving the navigation to Natrona, about twenty-four miles above the mouth, and the scheme contemplates an extension to Oil City, 134 miles above Pittsburg. The Western Division of the Pennsylvania Canal followed the Conemaugh, Kiskiminetas and Allegheny rivers from Johnstown to Allegheny; a connection to Kittanning, from the mouth of the Kiskiminetas river up the west bank of the Allegheny river was begun but never completed, while the French Creek division followed that creek and Conneaut lake outlet to Conneaut lake, Crawford county, enroute to Erie. All of these canals are now abandoned.

There is no water power generated on the main stream, and only a small amount on the tributaries, principally on those from the west, whereon some suitable sites still exist undeveloped.

There is a marked difference between the character of the tributaries of the Allegheny river coming from the east, and those from the west. The latter drain territory including lakes, ponds and swamps, where the surface conditions aid in equalizing the flow of

the streams, while those from the east are from a more precipitous country largely denuded of forests, and are of a flashy nature. The Kiskiminetas river drains the Cambria and Somerset bituminous coal fields, and many streams in this section are injured by coal wastes.

The oil and natural gas fields of Western Pennsylvania lie largely in the drainage basin of the Allegheny river and a small amount of timber of merchantable value is still standing in the extreme eastern section of this sub-basin.

The prominent towns in the Allegheny basin are Warren, Oil City, Franklin, Kittanning, Blairsville, Latrobe, Johnstown, Tarentum, Pittsburg, Indiana and Allegheny. The rainfall over this sub-basin averages 42.3 inches yearly.

The flow of the Allegheny is being measured at Red House, New York, Kittanning and Aspinwall, Pennsylvania. The average discharge at Kittanning since 1904 has been 18,050 cubic feet per second, or 2.08 cubic feet per second per square mile. The maximum was 242,000 cubic feet per second, or 27.8 cubic feet per second per square mile, and the least flow during this period was 1,650 cubic feet per second, or 0.19 cubic feet per second per square mile.

MONONGAHELA RIVER.

The Monongahela river is formed by the junction of two branches which rise in the mountains of West Virginia, from which point, 36 miles beyond the Pennsylvania-West Virginia line, it follows a general northerly direction to its mouth at Pittsburg. It crosses the State line one and one-half miles above Point Marion, West Virginia, and passes through the bituminous coal fields of southwestern Pennsylvania. The drainage basin of this stream in Pennsylvania is largely made up of rolling hills, from which the timber has been removed, except in the upper portion, and in that part of the territory which lies outside of the coal measures. The stream is sluggish, the natural grade for the 91.6 miles in Pennsylvania being 0.85 feet per mile. Its total length to the forks in West Virginia is approximately 128 miles, 91.6 miles of which are in Pennsylvania. It drains a total area of 7,329 square miles, 2,724 square miles being in Pennsylvania. Its principal tributary is the Youghiogheny river, which unites with it at McKeesport, about 14 miles above the mouth, draining 1,800 square miles, of which 1,286 square miles are in Pennsylvania. There are no other tributaries of any considerable size in Pennsylvania except the Cheat river, which comes in from West Virginia just below the State line.

Navigation has been improved on the main river throughout its length in Pennsylvania by the United States Government, by means of a series of dams and locks, through which great quantities of

coal are shipped from the mines to Pittsburg and thence down the Ohio river. Slack water navigation was at one time formed on the Youghiogheny river from its mouth up to West Newton, 19 miles, but was destroyed by the floods of the early 60's and has not been reconstructed, although the United States Government has this now in contemplation.

Most of the large streams in the section of the Monongahela river drainage basin covered by the bituminous coal fields have been impaired for many purposes by the discharge of mine wastes therein, so that the available water supply in this district is limited. The principal streams which remain undefiled and of value are those in the extreme upper section in Pennsylvania, outside of the coal measures, together with some which join the Youghiogheny river from Somerset county. Nearly all the streams in this whole area are subject to sudden rises and to low dry weather flow. The average rainfall is 41.4 inches over this sub-basin.

Water power is practically undeveloped. There is none used on the Monongahela and Youghiogheny rivers, and only an occasional small mill on the tributaries. The Youghiogheny river being an extremely rapid stream, affords several water power sites.

The principal towns in this drainage basin are Braddock, McKeesport, Monessen, Connellsville, Uniontown, Greensburg, Homestead and Pittsburg. The stream is followed by the Pennsylvania, the Baltimore and Ohio, and the Pittsburgh and Lake Erie railroads.

The river in its lower section is lined with large manufacturing plants, many of which use its waters for boiler and other purposes. It has been estimated that the dry weather flow of the Monongahela river is used twenty times by these mills and factories.

TABLE NO. 11.

Principal Streams in Ohio Basin.

Name of Stream.	Approximate drainage area in square miles.	Tributary from
Ohio river,	*21,604	†
Allegheny river,	11,160	N. Y. and Pa.
Conewango creek,	935	N. Y. and Pa.
Tionesta creek,	455	Penna.
Brokenstraw creek,	300	Penna.
Oil creek,	305	Penna.
French creek,	1,175	Penna.
Clarion river,	1,190	Penna.
Red Bank creek,	545	Penna.
Mahoning creek,	390	Penna.
Kiskiminetas river,	1,850	Penna.
Conemaugh river,	1,400	Penna.
Stony creek,	460	Penna.
Loyalhanna creek,	300	Penna.
Black Lick Creek,	385	Penna.
Monongahela river,	7,329	Penna.
East branch,	.....	W. Va.
West branch,	.....	W. Va.
Cheat river,	1,390	W. Va.
Youghiogheny river,	1,800	.....
Casselman river,	450	Pa. and Md.
Laurel Hill creek,	118	Penna.
Indian creek,	140	Penna.
Beaver river,	3,040	Penna.
Neshannock creek,	245	Penna.
Shenango river,	765	Penna.
Mahoning river,	1,070	O. and Pa.
Connoquenessing creek,	870	Penna.
Slippery Rock creek,	440	Penna.
Raccoon creek,	190	Penna.
Little Beaver river,	.....	O. and Pa.

*Above Pennsylvania-Ohio State line.
†N. Y., Pa., Md. W. Va.

TABLE NO. 12.

Comparative Flow of Principal Rivers.

River.	Station.	Drainage area in sq. mi. above station.	Maximum flow in cu. ft. per sec.		Average flow in cu. ft. per sec.		Minimum flow in cu. ft. per sec.		Length of Rec. Yrs.
			Total.	Per sq. mi.	Total.	Per sq. mi.	Total.	Per sq. mi.	
Delaware,	Lambertville, N. J.,	6,855	250,000	36.5	14,150	2.07	1,200	0.175	10
N. Branch Susuehanna,	Danville,	11,100	304,800	27.5	17,990	1.6	822	0,074	7
W. Branch Susquehanna,	Willlamsport,	5,640	164,100	29.0	9,130	1.6	410	0.072	12
Susquehanna river,	Harrisburg,	24,030	700,000	29.2	38,350	1.6	2,330	0.093	17
Allegheny river,	Kittanning,	8,690	242,000	27.8	18,050	2.08	1,650	0.19	3
Ohio river,	Wheeling, W. Va.,	23,800	473,400	20.0	40,400	1.7	2,500	0.105	.....

POTOMAC BASIN.

The drainage from Pennsylvania into the Potomac river is by creeks flowing in a southerly direction into that river in Maryland, the principal streams in this basin being Wills, Conococheague, Little Antietam, Sidling and Rock creeks.

LAKE ERIE BASIN.

The drainage into Lake Erie is northward through Elk creek and a number of small streams, and by Conneaut creek, northwesterly into Ohio and thence to the lake.

GENESSEE BASIN.

The Genessee river, rising in the northern part of Potter county, passes northward out of the State into New York, receiving several small tributaries which unite, drain into the Genessee basin.

The following tables show the principal tributaries in the three last described basins, and the area drained by each:

TABLE NO. 13.

Principal Streams of Genessee Basin.

Name of Stream.	Approximate drainage area in square miles.	Tributary from
Genessee river,		
Middle Branch Gen. R.,		
West Branch Gen. R.,		
.....	92	Penna.

TABLE NO. 14.

Principal Streams of Erie Basin.

Name of Stream.	Approximate drainage area in square miles.	Tributary from
Lake Erie, ...	*490	
Conneaut creek, ...	160	Penna.
Elk creek, ...	120	Penna.

*Total area tributary to Lake Erie from Pa.

TABLE NO. 15.

Principal Streams in Potomac Basin.

Name of Stream.	Approximate drainage area in square miles.	Tributary from
Potomac river,	*1,555	Penna.
Wills creek,	270	Penna. and Md.
Licking creek,	195	Penna. and Md.
Conococheague creek,	580	Penna. and Md.
Antietam creek,	305	Penna. and Md.

*Total drainage area tributary to Potomac in Penna.

CHARACTERISTIC FEATURES OF DRAINAGE BASINS.

Certain features of the different drainage basins and sub-basins play important parts in forming the character of the streams and their tributaries, and the use to which they are put. The Delaware Basin is distinctly an anthracite coal, cement, slate and stone producing and transportation area, with its coal mines in the upper section of the Lower and Middle Sub-basins, and the canals and railroads therefrom to the sea-coast.

The Susquehanna Basin is an anthracite coal producing area (southeastern part of the North Branch Sub-basin) and bituminous coal area (West Branch and the Juniata River), and the present lumber centre of Pennsylvania (extreme northern part of the West Branch Sub-basin). The lower portions of these two sub-basins are distinctly transportation areas for the products of the northern and western sections of the State. The lower Suquehanna Sub-basin is probably the most productive agricultural region of the Commonwealth.

The Ohio basin produces, from the Monongahela Sub-basin, vast quantities of bituminous coal, and from the Allegheny and the Ohio Sub-basins, bituminous coal, and most of the oil and gas which is produced in the State. Surrounding Pittsburg in all three sub-basins is located the greatest industrial centre in the State where steel, iron, coke and glass are the chief products. The refuse from these industries supplements the mine drainage in fouling the normal flow of the streams.

The Potomac Basin contains the least populated part of the State and is largely given over to agriculture and forest growth.

TOPOGRAPHY.

The southeastern corner of Pennsylvania is a generally level plateau, lying in the coastal plain and the Piedmont Plateau region, broken by rolling hills and drained my many streams, whose erosion has carved out valleys from the original level surface. The lower portions of the Delaware, Schuylkill and Susquehanna rivers pass through this region, which varies in elevation from a few feet above tide water to about 500 feet above sea-level.

To the north and west this plain is bounded by the Allegheny mountains and the Kittatinny mountains. These ranges traverse the State from northeast to southwest meeting the Delaware river at Delaware Water Gap, crossing the Lehigh river at Lehigh Gap, the Schuylkill at Port Clinton, and the Susquehanna river at Rockville, a few miles above Harrisburg. These ranges form a band approximately 70 miles wide from the extreme northeastern corner, in a reverse curve, to the southwest, leaving the State near the centre of the southern boundary.

The high plateau which extends northward and westward from the mountains has been deeply cut by many streams, so that the water courses often lie in deep valleys bordered by high hills, presenting almost mountainous characteristics. This region covers nearly one half of the State. In the extreme northwest a narrow, level plain follows the shore of Lake Erie. The southeastern plain is drained entirely by the Delaware and Susquehanna rivers, the mountainous belt largely by these two and the Potomac river, while the plateau region in the west lies in the basins of the Genessee, Allegheny, Monongahela and Ohio rivers.

The topography of the States varies from tide water, at Philadelphia, to 3,136 feet above sea level, on the top of Blue Knob, Bedford county. The Delaware river where it leaves the State is a tidal stream. The Susquehanna river where it crosses the southern boundary is above the influence of tides, its normal surface being 69.0 feet above sea level. The Ohio river in passing the westerly boundary of the State is 647 feet above sea level. Water from Pennsylvania flowing into Lake Erie leaves the State 573 feet above sea level, and the Genessee river, at an elevation of about 1,610 feet.

Owing to the length and the difference in elevation through which many of these streams pass, their physical characteristics change materially from source to mouth. Heading in the Allegheny mountains, the tributaries of the Susquehanna, Allegheny and Monongahela rivers are mountain brooks in their upper regions, becoming less rapid as they near the limits of the State, and changing with the increase from numerous tributaries into broad rivers.

Many of the streams in the Delaware and Susquehanna basins cross the Piedmont Plateau, and in most cases a fall line is to be

observed at the escarpment. The Susquehanna river has cut down considerably through this fall, but an increased velocity, narrow channel, and steep grade mark the point on this stream. This has resulted in the gorge-like character of the Susquehanna river from a point about 12 miles below Columbia, nearly to the State line. On the Delaware river this point is marked by the falls above Trenton.

GEOLOGY.

The surface and sub-surface geology have an important bearing on the flow of streams, as their character is largely dependent upon these elements, and an understanding of the elementary geological conditions in a region is essential to a proper knowledge of the streams.

The strata upon which the surface wash and soils of Pennsylvania repose belong to the oldest sedimentary rocks of the Palaeozoic series. No large amounts of igneous or volcanic rock appear in the State, the only intrusive materials being a few dikes of trap and small areas of granitic rock, of which all are in the southeastern part of the State. The Appalachian mountains are made up of limestone, slates and sandstones. In the limestone areas are found many springs of remarkable volume.

The Terminal Morain, marking the southern limit of the glaciers, crosses the State from east to west in its northern part, dipping further to the south at each end, and leaving the northern boundary in Warren county to return again in Potter county.* The broad, high table-land in the Appalachian bituminous coal field, terminating on the confines of New York, has evidently stopped the southward course of the nearly spent sheets of ice which transported the drift and turned them off to the southeast and southwest.

The portion which was originally glaciated has been left with a covering of gravel and boulder drift. The glacial remains hardly touch Potter and McKean counties, but are strewn more freely over Bradford, Susquehanna and Wayne counties, in the east, and Warren, Crawford, Erie and Elk counties, in the west. It is noted that the line of the Terminal Morain is comparatively smooth, with few tonges and fissures.

LAKES.

In this once glaciated region there are lakes, ponds and marshes, formed by the blocking of outlets and by the leveling of the country by moving glaciers. Among these are the lakes of Lackawanna, Wayne, Pike, Wyoming, Luzerne, Susquehanna, Monroe, and Sullivan counties in the east, and the great swamps and extensive lakes

*See map page 23.

of Erie and Crawford counties in the west. Prominent among these lakes are Conneaut, Canadohta and Sugar lakes in Crawford county; LeBouf lake in Erie county; Lewis and Hunter lakes, Sullivan county, Elk lake, Still pond, Crystal lake, Silver lake, Susquehanna county; Belmont lake, White Oak pond, Lake Ariel in Wayne county; Big Brink pond, Log Tavern ponds, Beaver lake, Lake Laura and Porter's lake, Pike county; Long pond, Monroe county; Moosic lake, Canuga lake, Lackawanna county; Lake Carey and Lake Wyonia, Wyoming county, and Harvey's lake and Crystal lake in Luzerne county. The streams rising in this once glaciated region are less subject to sudden rises or to such low dry weather flow than the streams to the south.

Professor H. Carvill Lewis states in report "E," Second Geological Survey of Pennsylvania, that in Pennsylvania and New Jersey there are about 2,000 lakes lying back of the Terminal Morain, and scarcely any in front of it. He further states that there are two classes of lakes in the glaciated area of Pennsylvania, the first being due to the damming of streams, or the choking of the original drainage system thereof by the irregular deposits of the drift; and the second, those lakes which, with neither apparent inlet not outlet, fill "kettle holes," or depressions in the Morain itself. Long pond is of the former class, and lakes Poponoming and Mineola, Monroe county, are of the latter class.

SPRINGS.

Both mineral and non-mineral springs are found in the Commonwealth, Bedford Mineral Springs, Bedford county and Cambridge Mineral Springs, Crawford county, have achieved national prominence.

Non-mineral springs abound in many parts of the State, the largest being found in the limestone regions of Centre, Huntingdon, Cumberland, Lebanon, Lehigh and Northampton counties. Many small towns and some boroughs of considerable size are supplied with water obtained from these springs.

CHAPTER IV.

DEFORESTATION AND ITS EFFECT ON STREAM FLOW.

A study of the streams of Pennsylvania demonstrates that their value to the Commonwealth as a natural resource has been and is being materially decreased. As settlement progresses one of its steps is to destroy the forests; wood is needed for building, fuel, timbering mines, etc., trees are cut down and little regard is paid to subsequent regrowth, and to the results which may follow. When the trees are removed, the rain and melting snow flow rapidly from the denuded areas, eroding the soil and rushing off in torrents, while in forest covered country much of the rain is absorbed by the mould, moss and leaves, and held by the forest floor. By denudation floods are increased in volume and frequency, the low water periods are lengthened and the minimum flow decreased.

By irregular flow the quality of the water is affected, for, in the erosion of denuded hills and valleys, the streams accumulate quantities of earth and other material which is carried by the water in suspension to points below, where much of it is deposited to obstruct the channel. The high turbidity of a water adds to the cost of its utility for many purposes.

The study of the effect of deforestation upon the flow of streams has received considerable attention in this country and abroad. While no positive statements of general acceptance can be made relative to the definite decrease in run-off caused by the reduction of the woodland in the drainage basin of streams, nevertheless, it is generally believed by observers that the destruction of a dense forest on a water-shed is almost universally accompanied by a reduction of the available annual yield to stream flow.

Data of scientific value on this subject are lacking in Pennsylvania. There has heretofore been no public body interested in this subject to the extent of determining the effect of the removal of the forests upon the run-off of the streams and now that the forests are so largely removed it is difficult to make investigations, except by comparing the flow of two streams, upon the drainage basins of which are very different percentages of forest cover. Such comparisons may, however, be misleading, for other differences than the amount of forest may exist.

The records to be of real value must extend over a long period of years, so that it is necessary to rely largely on data obtained in other states for our deductions, as to the effect on the streams of Pennsylvania. A few examples will show, however, the decreased

flow in recent years of some of the Pennsylvania streams, but it is not possible to prove that this decrease is due solely to cutting away of forests. The streams upon which we have discharge data for long periods are in portions of the State in which the process of deforestation on a large scale had materially decreased before the records of flow were begun, and although some of these records show a decided reduction in the stream flow over past years, this is not so marked as it might have been if the records extended back ten or twenty years further. Nevertheless, these data, and intelligent public opinion, indicate that our streams are becoming more irregular in flow; and, as we know the destruction of the forests to have wrought changes in neighboring states, we may justly apply this cause to our conditions, and endeavor to reduce in every way an influence evidently so detrimental to the flow of streams.

The following table shows the August and September, and also the yearly total rainfall, run-off and evaporation on the Perkiomen creek water-shed from 1883 to 1903. This stream has a drainage area above the point of measurement of 152 square miles, and was, at one time, investigated as a possible source of supply for Philadelphia.

TABLE NO. 16.

Rainfall and Run-off on Perkiomen Creek.

Year.	August.		September.		Total Annual.			
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Evaporation.	Per cent. running off.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1883-84, ...	3.41	0.65	0.59	0.31	48.57	31.90	16.67	65.6
1884-85, ...	6.17	1.23	.87	.16	38.12	18.41	19.71	48.3
1885-86, ...	1.44	.35	1.37	.23	47.78	25.54	22.24	53.5
1886-87, ...	2.76	1.43	3.64	.62	50.16	21.33	28.83	42.5
1887-88, ...	8.03	1.53	7.35	3.68	50.31	26.35	23.96	52.4
1888-89, ...	3.99	2.48	7.00	2.80	60.20	30.82	29.38	51.3
1889-90, ...	6.75	1.08	3.71	1.36	56.15	31.56	24.59	56.1
1890-91, ...	7.57	2.04	2.63	1.53	50.44	25.35	25.09	50.2
1891-92, ...	2.69	.76	2.21	.33	42.43	19.76	22.67	46.5
1892-93, ...	6.45	.96	3.14	.60	44.62	21.96	22.65	49.2
1893-94, ...	2.23	.31	6.36	1.67	46.54	22.22	24.32	47.8
1894-95, ...	3.36	.28	.93	.18	44.07	20.52	23.55	46.6
1895-96, ...	1.21	.31	5.18	.65	45.54	14.31	31.23	31.4
1896-97, ...	2.73	.58	1.62	.29	44.75	19.28	25.47	43.1
1897-98, ...	6.16	.63	2.22	.22	44.86	19.29	25.57	42.9
1898-99, ...	4.46	1.13	7.46	2.44	56.10	29.06	27.01	51.8
1899-00, ...	3.74	.41	1.80	.24	34.62	16.47	18.15	47.5
1900-01, ...	8.70	1.39	3.27	.63	44.89	13.49	31.40	30.0
1901-02, ...	4.66	.52	7.54	1.21	50.27	24.25	26.02	48.2
1902-03, ...	.....	.....	.....	.....	52.84	31.96	.....	60.1
Mean for 20 yrs.,..	4.52	.96	3.63	1.01	47.66	23.19	24.66	.....

From this table it is seen that the evaporation has been gradually increasing during these 20 years, and that, consequently, the ratio of run-off to rainfall has been decreasing. During the 10 years from 1883 to 1893 the average ratio of run-off to rainfall was 51.46 per cent., while in the 10 years from 1893 to 1903 it was 44.97 per cent.

Neshaminy creek, near Philadelphia, shows a similar condition, although not so marked. The ratio of run-off to rainfall for an average of 10 years, from 1883 to 1903, was 49.70 per cent. For the ten years, 1893 to 1903, it was 46.28 per cent. These two streams have been gauged by the Philadelphia Bureau of Water for 23 years, and the above figures are based upon its measurements.

In March, 1894, the Pennsylvania State Forest Reservation Commission sent out a list of questions to all counties in the State, in the endeavor to determine local opinion as to the question of decreased low water flow and its cause. The replies were not the scientific judgment of men trained in the study of stream flow, but their general agreement has great significance.

In answer to the question whether the correspondent could "name and locate stream or streams in which there has been a change in quantity of water carried," 174 replies were received. Of these, 127 named streams and qualified the reply to show that this change was a reduction which was considered due largely to the destruction of the forests; three stated that the streams were improving, and 12 that they saw no change.

In connection with the investigation of this Commission relative to water powers the question was asked whether or not the stream utilized was deteriorating from the standpoint of the water power producer. Of 248 replies, 113 stated that the stream was deteriorating, 109 that there was no perceptible change, and 26 that the stream was improving. The result of these replies is somewhat at variance with that of the Forestry Commission, above recorded. They show only 45.5 per cent. stating that the streams are deteriorating, against 73 per cent. by the results of the question of the Forestry Commission. The questions of the Water Supply Commission were sent out 12 years later than those of the Forestry Commission, and therefore reflect existing conditions at this later date.

In most of the State extensive deforestation resulted many years ago, and, in all probability, the experience of the parties answering the later questions does not extend back to the period preceding the forest destruction. This indicates, therefore, that many of the streams of Pennsylvania are not now growing worse, having previously reached the deteriorated condition caused by the deforestation of their drainage areas, and are remaining stationary, at a lower efficiency, while some few are slowly improving with the regrowth of young timber.

The following table shows in marked manner the difference in the run-off from forested and barren areas:—

TABLE No. 17.

Comparison of flow from Forested and Barren areas in New Jersey, in 1881.* (Flow in gallons per square mile during the last eight months of the dryest year, 1881).

Months	Watersheds.	
	Passaic River, forested.	Barren watersheds.
April,	597,000	631,000
May,	297,000	145,000
June,	272,000	139,000
July,	207,000	22,000
August,	140,000	23,000
September,	139,000	23,000
October,	129,000	22,000
November,	129,000	23,000
December,	127,000	.....

*From report of State Geological Survey of New Jersey.

Again this difference is well shown by the record of two small streams in Delaware county, Pennsylvania, as measured by Henry Birkinbine, Engineer, of Wayne, Pennsylvania.

"Gaugings were taken of the two streams at points where the areas above the weirs were in each case one square mile. One stream flowed through woodland, and the other through open but cultivated country. These gaugings were carefully taken, at first daily, and afterward two or three times a week and were practically simultaneous at each stream."

TABLE No. 18.

Comparison of flow from two Streams of one Square Mile Drainage area each, one Forested and one Barren.*

Date.	Yield from forested stream in gallons per minute.	Yield from barren stream in gallons per minute.
For month of August, 1896,	31.02 to 64.7	13.11 to 37.76
September 6, 1896, after an all night rain,	50.10	54.06
September 8, 1896,	31.02	7.97
Early part of October, 1896,	31.02	10.4
October 12, 1896, immediately after a severe rain,	127.	165.
November 6, 1896, heavy rain,	61.36	83.22
November 7,1896, rain,	50.1	63.30
For month of November, 1896,	33.00 to 98.96	25.83 to 192.72
For month of December, 1896,	55.69 to 67.95	73.08 to 122.75
January, 1897, two measurements,	85.72 to 112.69	73.08 to 122.22
February, 1897, two measurements,	98.96	104.88 to 152.94
March, 1897, six measurements,	25.83 to 85.72	45.31 to 179.10
April, 1897,	88.07 to 119.84	93.84 to 128.16
May, 1897, two measurements,	88.97 to 112.69	73.08 to 122.02

*From 1897 report Pennsylvania Department of Agriculture, Bureau Forestry.

From these records it is seen that the extremes of flow were greater from the barren stream, that in the summer or dry weather months the flow was less in the barren stream, and that directly after rains the deforested stream reached a higher rate of run-off and soon fell to a lower rate than that having a forested drainage area.

Recognizing, therefore, this influence on the character and quantity of the run-off in the streams, this Commission has obtained, through the co-operation of the U. S. Geological Survey, reliable data concerning the location of the forest covered areas in the State, and has recorded such areas upon its maps. This has made it possible to determine the percentages of certain drainage areas which are forest covered, from which information much light is thrown upon the character of stream run-off. There remains but about one-fifth of the original forest land which at one time nearly covered the State, with an area considerably larger which is unfit for agriculture, but covered with the remnants of burned or cut timber, and now slowly growing into forests where protected from cattle and fire. Sparks from locomotives and the burning of debris along the railroad tracks are the cause of many forest fires, and for their own protection the railroads should guard the forests traversed by their tracks. Some railroads, appreciating the need of timber for their own use, have organized forestry bureaus and have taken steps to reforest certain areas. If this practice were followed by all the railroads of the State it would result in more care of existing forests and a corresponding decrease in forest fires.

This Commission heartily endorses the work of the Forestry Reservation Commission of Pennsylvania in the work it is doing in establishing State forest reservations, and in its work of instruction in scientific methods of lumbering and forest culture. It strongly recommends an increase in the amount of forest lands set aside and preserved, for such areas form storage reservoirs at the head waters of the rivers of the State, and their value as such cannot be over-estimated. The Forestry Reservation Commission has acquired, to January 1st, 1908, 752,058 acres of land, much of which surrounds the headwaters of streams. These areas are actively patrolled and protected from fire and other forms of destruction, and their influence upon the flow of the streams heading therein is most beneficial. Legislation now pending in the Federal Congress, providing for national forests in the Appalachian mountains, extending over the head waters of the Monongahela river in West Virginia is favored by this Commission.

In order, however, to preserve the present value of our streams, steps must be taken to care for both public and private forest lands in the State. Fire is destroying thousands of acres of timber yearly,

and water companies have complained to this Commission of reduction in the value and usefulness of their works, caused by a decrease of the available water supply, resulting from forest fires in the drainage area of the streams from which their supplies are derived. Legislation and education along these lines seem imperative for the proper conservation of the water supplies of the Commonwealth. It is seen from Table No. 19, that the destruction through forest fires has decreased greatly since 1900, due to the enforcement of protective laws and in a large measure to the fact that railroads and the people generally are more careful.

The following table shows the relative rate of cutting timber, and of its destruction by fire in Pennsylvania, from 1900 to 1906, inclusive.

TABLE No. 19.

Acreage Lumbered and Burned in Pennsylvania.

Year.	Lumbered.	Burned.
1900	172,854	266,027
1901,	133,595	73,005
1902,	160,368	158,572
1903,	125,981	64,186
1904,	134,679	63,211
1905	131,600	18,642
1906,	.....	44,495

TABLE No. 20.

Causes of Forest Fires—Percentage of Total Fires due to Various causes.

Year.	Railroad.	Incendiary.	Brush Burning.	Unknown.
	Per cent.	Per cent.	Per cent.	Per cent.
1902,	26	12	12	38
1903,	29	9	9	.....
1904,	29	9	.....	.....
1905,	33	10	.....	.....
1906,	26	13	.....	.....

For years the lumbering industry in this State has been largely confined to the West Branch of the Susquehanna river and the upper portion of the Allegheny sub-basin. The following information, with relation to the deforestation of the water shed of the West Branch of the Susquehanna, is taken from page 17, Report on Flood Protection for the city of Williamsport, 1895.

Lumbering operations were commenced in this region in 1850, but no systematic record of the amounts cut was kept until 1862. In the latter year the cut was 38,000,000 feet B. M. It rapidly increased until it obtained its maximum of 319,000,000 feet in 1873,

and then fell to about 212,000,000 feet in 1890. The total amount cut since 1862 is about 5,250,000,000 feet B. M., which represents about 30,100,000 logs. In the year 1880 the timber on nearly 700,000 acres of land in Pennsylvania was destroyed by fire. This is nearly as large an area as is contained in all the forest reservations owned by the State to-day. The above statements are based on the Census report for 1880, and on information furnished by Mr. George S. Banger, Secretary of the Susquehanna Boom Company.

Many laws have been enacted to reduce forest destruction by fire. In the early colonial days these laws forced the payment of damages by the offender to the party damaged, but in more recent years the injury to the State has been recognized by the legislature, and this offense is punishable by fine and imprisonment. These laws, however wisely made, are useless if not enforced. It is not through laws alone that forest fires can be reduced, but by educating the people of the Commonwealth to a proper understanding of the value and usefulness of forests.

From the foregoing discussion it is evident, then, that forests are of value as regulators of stream flow, reducing floods and increasing dry weather discharge. The most direct and apparent effect of the reduction of dry weather flow by deforestation is the decrease in the available water supply for domestic and manufacturing purposes. From a similar cause the value of the stream for the generation of water power is reduced, for without storage reservoirs or stream reinforcement the dry weather flow limits the power which can be economically developed. The cost of improved navigation on our rivers will also be increased over what it would have been had forest reduction not lessened the volume of water during the dry seasons, while its maintenance will usually be more costly on a stream which has a small proportion of its drainage area in forest because of the larger quantities of sediment deposited by such streams.

CHAPTER V.

STREAM FLOW.

In any investigation of the water resources of a region the item of prime importance is the dependable quantity of water flowing in the streams; and accurate knowledge thereof is essential to the proper conservation, protection and distribution of the waters of the Commonwealth. Reliable records are available at few points, chiefly on the large rivers, and on a few smaller streams scattered over the State. Of the flow of the vast majority of the secondary and small streams practically nothing is known. Expected sources of such information are often without satisfactory data and prove the necessity for the inauguration of stream measurements by the State. New York, New Jersey, Massachusetts and other Eastern States have much more thorough knowledge of their water resources than has Pennsylvania.

The records of the Hydrographic Branch of the United States Geological Survey constitute the bulk of the reliable stream discharge data available for Pennsylvania. The first station to be established in the State by this bureau was at Harrisburg, on the Susquehanna river, in 1890. It was followed, in 1895, by one at Williamsport, on the West Branch of the Susquehanna river, and others have been established by this organization from time to time. Congress had appropriated annually $200,000.00 for this work in the entire United States; but at the session of 1906 this amount was cut to $150,000.00, necessitating a reduction in the number of stations operated, and in 1907 it was still further reduced, so that on April 1st, 1907, the bureau considered it necessary to discontinue all observations east of the Mississippi river.

On January 1st, 1907, the stations discontinued by the United States Geological Survey during the previous summer were reestablished by the Water Supply Commission, and on April 1st all the stations in Pennsylvania, then operated by the United States Geological Survey, were taken over and have since been maintained by this Commission and new stations established.

Other valable records are those of the flow of the Perkiomen, Neshaminy and Tohickon creeks, in the vicinity of Philadelphia, which were begun in 1884 and have been continued by the Philadelphia Bureau of Water. A few short term records, scattered over the State, complete the list of reliable data of stream flow in Pennsylvania, so far as we have been able to determine.

The following table gives the discharge measuring stations, the period of observation and the organization now operating them, and includes stations on streams entering Pennsylvania from, or flowing from Pennsylvania into, other states.

TABLE No. 21.

Gauging Stations on Pennsylvania Streams.

Station.	Established.	Discontinued.	Re-established.	Direction.
SUSQUEHANNA BASIN.				
Susquehanna River.				
1. Binghamton, N. Y.,..	August 1-01	.....	.....	U. S. G. S.
2. Wilkes-Barre, ...	March 30-99	.....	.....	Observer pd. by U. S. Weather Bureau. Gaugings made by Water Supply Commission.
3. Danville, ...	March 25-99	July 15-06	September 06	Established by U. S. G. S. Re-established by Water Supply Commission.
4. Harrisburg, ...	1890	.....	.....	Observer pd. by U. S. Weather Bureau. Gaugings made by Water Supply Commission.
5. McCall Ferry, ...	May 17-02	.....	.....	McCall Ferry Power Co.
Chenango River.				
6. Binghamton, N. Y.,	August 1-01	.....	.....	U. S. G. S.
Chemung River.				
7. Chemung, N. Y.,....	Sept 7-03	.....	.....	U. S. G. S.
West Branch Susquehanna River.				
8. Allenwood, ...	March 25-99	April 02	.....	U. S. G. S.
9. Williamsport,, ...	March 1-95	.....	.....	Observer pd. by U. S. Weather Bureau. Gaugings made by Water Supply Commission.
Juniata River.				
10. Huntingdon (Franks-town Branch).	July 24-07	.....	.....	Established by Water Supply Commission. Observer paid by Juniata Hydro-Electric Co.
11. Hawn's Bridge (Rays-town Branch).	July 25-07	.....	.....	Established by Water Supply Commission. Observer paid by Raystown Water Power Company.
12. Newport, ...	March 21-99	July 15-06	Jan. 4-07	Established by U. S. G. S. Meter measurements made by Water Supply Commission.
Octoraro Creek.				
13. Rowlandsville, Md.,.	Nov., 1906	Sept., 1899	.....	U. S. G. S.
Deer Creek.				
14. Churchville, Md., ...	Dec. 14-04	.....	.....	U. S. G. S.
Broad Creek.				
15. Mill Grove, Md., ...	Dec. 14-04	.....	.....	U. S. G. S.
DELAWARE BASIN.				
West Branch Delaware River.				
16. Hancock, N. Y., ...	Oct. 15-02	.....	.....	U. S. G. S.
East Branch Delaware River.				
17. Hancock, N. Y., ...	Oct. 14-02	.....	.....	U. S. G. S.
Neversink River				
18. Port Jervis, N. Y., ..	Oct. 16-02	August 3-03	.....	U. S. G. S.
19. Godeffroy, N. Y., ..	August 4-03	.....	.....	U. S. G. S.
Delaware River.				
20. Riegelsville, N. J., ..	July 3-06	.....	.....	U. S. G. S.
21. Lambertsville, N. J.,	July 22-97	.....	.....	U. S. G. S.

TABLE NO. 21—Continued.

Station.	Established.	Discontinued.	Re-established.	Direction.
Tohickon Creek.				
22. Point Pleasant, ...	1885	.....	.....	Philadelphia Bureau of Water.
Neshaminy Creek.				
23. Below the Forks, ...	1884	.....	.....	Philadelphia Bureau of Water.
Schuylkill River.				
24. Fairmount Dam, ...	1885	.....	.....	Philadelphia Bureau of Water.
Perkiomen Creek.				
25. Frederick, ...	August 1884	.....	.....	Philadelphia Bureau of Water.
Wissahickon Creek.				
26. At Mouth, ...	April 1897	.....	.....	Philadelphia Bureau of Water.
Lehigh River.				
27. So. Bethlehem, ...	Sept. 22-02	Feb. 15-05	.....	U. S. G. S.
OHIO BASIN.				
Ohio River.				
28. Wheeling, W. Va., ..	1905	.....	.....	U. S. G. S.
Mahoning River.				
29. Youngstown, O., ...	May 23-03	.....	.....	U. S. G. S.
Allegheny River.				
30. Red House, N. Y., .	Sept. 4-03	.....	.....	U. S. G. S.
31. Kittanning, ...	August 18-04	.....	.....	Established by U. S. G. S. Meter readings made by Water Supply Commission.
32. Aspinwall, ...	May 28-07	.....	.....	Pittsburg Bureau of Water.
Chadokoin River.				
33. Jamestown, N. Y., ..	April 3-01	March 18-05	.....	U. S. G. S.
Kiskiminetas River.				
34. Avonmore, ...	May 29-07	.....	.....	Established by Water Supply Commission.
35. Salina, ...	August 17-04	July 15-06	.....	Established by U. S. G. S.
Quemahoning Creek.				
36. Near Mouth, ...	October 01	.....	.....	Cambria Steel Company.
Mill Creek.				
37. Above Upper Reservoir.	August 01	.....	.....	Cambria Steel Company.
Hinkston's Run.				
38. At Reservoir, ...	January 02	.....	.....	Cambria Steel Company.
Black Lick Creek.				
39. Black Lick, ...	Oct. 16-04	July 15-06	January 07	Established by U. S. G. S. Re-established by Water Supply Commission.
Monongahela River.				
40. Lock No. 4, ...	March 1905	.....	.....	U. S. Army.
Cheat River.				
41. Morgantown, W. Va.,	July 8-99	.....	.....	U. S. G. S.
Youghiogheny River.				
42. Friendsville, Md., ..	August 17-98		1904	U. S. G. S.
43. Confluence, ...	Sept. 15-04	.....	.....	Established by U. S. G. S. Operated since April, 1907, by Water Supply Commission.
Casselman River.				
44. Confluence, ...	Sept. 15-04	.....	.....	Established by U. S. G. S. Operated since April, 1907, by Water Supply Commission.

TABLE NO. 21—Continued.

Station.	Established.	Discontinued.	Re-established.	Direction.
Laurel Hill Creek.				
45. Confluence, ...	Sept. 15-04	.....	.....	Established by U. S. G. S. Operated since April, 1907, by Water Supply Commission.
Indian Creek.				
46.	1892	1894	.....	Western Water Company.
Turtle Creek.				
47. East Pittsburg, ...	Oct. 31-07	.....	.....	Established by Water Supply Commission.
POTOMAC BASIN.				
Antietam Creek.				
48. Sharpsburg, Md., ...	Jan. 24-97	August 26-05	.....	U. S. G. S.
Wills Creek.				
49. Cumberland, Md., ..	May 5-05	July 15-06	.....	U. S. G. S.
Monocacy River.				
50. Frederick, Md., ...	August 4-96	.....	.....	U. S. G. S.

There is a total of fifty stations at which Pennsylvania streams have been systematically measured, of which ten have been discontinued, leaving forty in operation. Of these, seven are co-operative with Weather Bureau River Stage Observation Stations, and as fifteen of the forty are outside of the State there remain twenty-five stations which are now being regularly operated in Pennsylvania.

Since the Commission has assumed this duty five new stations have been established through co-operation with water-power companies and municipalities, as follows:

1. Allegheny river at Aspinwall, established May 28, 1907.
2. Kiskiminetas river at Avonmore, established May 29, 1907.
3. Frankstown Branch, Juniata river at Huntingdon, established July 24, 1907.
4. Raystown Branch, Juniata river at Hawn's Bridge, established May 28, 1907.
5. Turtle creek at East Pittsburgh borough, established October 31, 1907.

Past records at all the stations enumerated have been collected and arranged in proper form for use by those requiring such data. Data for streams at points outside of Pennsylvania are included, where measurements have been made of streams just previous to entering or after leaving the State, and may be assumed to indicate closely the flow entering or leaving the State through these channels.

An observation station consists of either a graduated board placed upright in the stream on a bridge pier or other convenient point,

or a chain with weight attached running along a graduated board, placed horizontally in a locked box on a bridge over the stream, the weight being lowered over a pulley by the observer to the water surface, and the length of the chain used, read on the graduation.

A paid observer, living in the vicinity of the gauge, reads the height of the water once, and, at some points, twice a day, and more often during the flood periods. Engineers visit these stations at regular intervals, and also at times of exceedingly high or low water, during which visits the cross-sections of the streams and the velocity of the current are determined by meter readings, and from these data the discharge in cubic feet per second is computed. In a few years it is possible in this way to establish a curve indicating the discharge in cubic feet per second, corresponding to any gauge height of the stream, so that the daily record, as reported by the local observer, can be readily converted into discharges.

The precipitation records at the nearest rainfall stations are then applied to the watershed above the gauging station, and the quantity of water falling upon it is determined. This quantity divided into that determined by the gaugings gives the percentage of the rainfall which runs off. These percentages are calculated by months and years, and their value depends upon the range between very high and very low water included in the records, while this, in turn, depends usually upon the length of the term of observation.

A few of the records at the stations listed above have been obtained from colleges in Pennsylvania, the actual field work and computations having been made by the students, under the supervision of instructors. Others have been furnished by various engineers and corporations, the gaugings having been made in connection with investigations for water supply and water-power developments. The methods of field work have, in every case, been inquired into before accepting the data.

In most cases where measurements have been made by engineers and corporations surface float velocities have been taken and the discharge computed therefrom and in few instances have these records been kept over any extended period, and where stream flow data was required for industrial developments, it is probable that where measurements were not available, deductions of flow were obtained from rainfall data.

A portion of water falling upon the earth runs off over the surface into the streams and rivers, while another portion sinks into the ground, and is slowly carried in the porous strata of the earth, often remaining underground for a considerable period before coming to the surface as springs, or being pumped from wells. The quantity of surface water can be determined by meas-

uring the streams, but the study of the underground flow is a more complex problem. It is essential that these underground conditions be known, and that provision be made for a thorough study of the ground water resources of the State, as well as of the surface waters.

The importance of knowledge as to ground waters is illustrated by comprehensive monographs published by the National Government and by litigation before the U. S. Supreme Court between the states of Kansas and Colorado.

Many influences control the variation of run-off among streams, the most important of which are rainfall, character of geology and topography, and amount of forest cover in the catchment area.

The useful effect of rainfall depends upon its amount and its seasonal distribution, and precipitation distributed nearly uniformly throughout the year encourages more regular stream flow than if it varies during the seasons. The nature of rains, whether sudden showers or prolonged storms, is also a factor. If the surface cover is deep soil, sand or other previous material, the flow is more regular and the minimum higher than if the rocks are bare or covered with only a thin layer of soil. A porous material holds water gathered during wet seasons, to distribute it during dry periods, resulting generally in large summer flow in streams draining such regions.

If the drainage basin be composed of abrupt hillsides and deep and narrow valleys, and if the profile of the stream be steep and its course straight, other conditions being the same, the stream flow will be more irregular than if this area be more level, with a flatter grade in the streams and a less direct course.

To illustrate the effect of such conditions upon the run-off of streams with drainage areas of approximately the same size, the records of the flow of the Youghiogheny and Casselman rivers, tributaries of the Monongahela river, during the dry season of 1904 are instructive. These streams meet at Confluence draining adjoining watersheds which extend into Maryland. The former has a drainage area of 392, and the latter of 482, square miles and the rainfall over the two basins is practically the same. During the dry season of 1904 the former reached a low water discharge of 27 cubic feet per second, equal to .068 cubic feet per second square mile of tributary drainage area, and the latter of 14 cubic feet per second, equal to .029 cubic feet per second per square mile. Thus the Casselman river, with a drainage basin nearly one-quarter larger than that of the Youghiogheny river, shows an extreme low water discharge but one-half as great.

The Commission has divided the streams of Pennsylvania into classes, in each of which typical streams are being gauged and

studied in order that the data so obtained may apply to the other streams of that class with a fair degree of accuracy.

These records of stream flow are of assistance in determining the distribution of water, studying flood conditions, deciding questions of encroachments on streams, and of incorporating water and water power companies. Moreover, a knowledge of the flow of streams is valuable to the users of water for domestic and manufacturing supply, for commercial purposes, such as navigation or canalization, and for water power development, while the information regarding flood discharge assists in studying the question of flood amelioration and in designing bridge and culvert openings. The distribution of this information throughout the Commonwealth should lead to a more economical use of the water supply, and materially assist in the design of works which involve the utilization of the water resources of the State.

CHAPTER VI.

FLOODS.

Pennsylvania is one of the worst sufferers from floods among the Eastern States. Provided with great rivers, it is not in position to reap full benefit from them until the damage from the floods is reduced. None of the streams, with the exception of the lower Delaware, is naturally navigable for ships, or even for boats drawing over three or four feet, during all seasons of the year, and if they are to be used for this purpose, navigation must be artificially improved. To make such improvements of permanent value, floods must be controlled or limited; hence this Commission has been devoting some study to the problem. It is not alone the large streams on which damage has been wrought, for many of the smaller streams overflow their banks with disastrous results, and in certain cases the damage has been increased by the failure of dams or embankments, thus releasing the additional water into the already overflowing channel.

In August, 1906, a portion of the Schuylkill river valley near Hamburg, Berks county, was visited by a sudden and severe rain storm, the precipitation amounting to two inches and causing the small streams to rise rapidly, flooding houses and industries, and seriously interfering with business operations. Kittanning, in Armstrong county, was visited about the same time by a storm of similar character with like results.

On August 3rd, 1906, a storm over a limited area in Schuylkill county transformed rivulets into roaring torrents which swept many buildings away and blocked railroad traffic for twenty-four hours. The streams affected by this storm were such unimportant tributaries of Swatara creek that few have been given names, yet in a short time these were converted into waterways fifty or more feet in width, and from four to ten feet deep. The crest of the flood lasted but a short time, and within a few hours the volume of water carried in the creeks was reduced to its normal amount. In the interval railroad embankments were cut away, considerable track moved bodily from its bed, live stock was drowned and buildings considered far above freshet influence were damaged or moved by the rushing water.

On June 7th, 1906, the heavy rainfall throughout the western part of the State resulted in an 18 foot stage at Johnstown, which submerged the lower part of the city and caused the water to rise to such a height in Connoquenessing creek at Butler as to neces-

sitate shutting down manufacturing plants, factories and mills, and rescuing many families from their homes. Other towns in the western section of the State suffered severe damage.

On Sunday, July 5th, 1903, the watershed of Brush creek in Westmoreland county was subjected to a rainfall of $5\frac{1}{8}$ inches over about 6 square miles. This water rushed down the creek valley, filling, overflowing and tearing out a reservoir embankment and sweeping an electric car from a bridge, thereby causing a loss of twenty lives.

In 1889 the central portion of the city of Philadelphia, about twenty square miles in area, was visited by a storm which overtaxed sewers and flooded streets, filling cellars and otherwise causing considerable financial loss. This storm, in less than two hours, deposited 5.42 inches of rain. In this case the damage inflicted was not due to the flooding of any stream, but simply to the fact that the sewers, although liberally proportioned, could not carry off the rain water as fast as it fell. In the cases noted above the stream channels were overtaxed, just as were the sewers in Philadelphia during this extraordinary precipitation.

Local storms of this character with results similar to those described may be expected on most of the streams, and as population and industry concentrate in the valleys the injury inflicted will increase. The rainfall in a general way is probably not changing from decade to decade, and there is no reason to believe that short severe storms are more frequent than formerly, but their effect on the streams is apparently more marked than when deforestation, agriculture and population were less extensive over the drainage basins.

Two historic floods have visited the western section of this Commonwealth, one noteworthy for the loss of life it caused, and the other for the financial loss which resulted. The former is known as the Johnstown Flood, June 1st, 1889, and the latter the Pittsburgh Flood, March 15th, 1907.

JOHNSTOWN FLOOD.

In the Johnstown Flood the loss of life was greater than the combined deaths resulting from all other recorded floods in the State, while the property loss alone in Johnstown has seldom been exceeded.

The high water and flood conditions were not confined to Johnstown and the streams in that vicinity, but were evident over the greater part of this and adjoining states, the unusually heavy and prolonged rains extending over a wide territory. The calamity at Johnstown, from which this flood has received prominence, would not have reached such appalling proportions had not the impounded

waters from a reservoir upon the South Fork of the Conemaugh river above Johnstown been added to the already overflowing stream.

The immediate cause of the fearful loss of life and property in Johnstown and the Conemaugh valley was the breaking of the South Fork Dam.

The records show what the extraordinary rainfall, averaging eight inches in depth over an area of more than 12,000 square miles, covering the mountain pleateau and its eastern declivities from Johnstown to Harrisburg, and extending northward in the Susquehanna Basin with flood rains of less intensity in the southern section of New York State, within said basin, beginning on May 30th, and lasting from 24 to 36 hours, was the greatest one of the century in Pennsylvania. This vast quantity of water caused streams to break their bounds and to shape channels anew in many places, artificial waterways were flooded, embankments were washed away, farms never before flooded were buried, and the canals along the rivers were wrecked.

Perhaps the best and briefest description of the damage accomplished by this flood may be found in the report of a Committee of American Society of Civil Enigneers appointed to investigate the conditions and report upon the cause of the flood and the damage done thereby. The following are excerpts from this report:

> "On their passage up the eastern slope of the Allegheny mountains they obsered many evidences of the magnitude of the flood, particularly in the destruction of bridges. Among these were three bridges over the Juniata river, on the main line of the Pennsylvania Railroad, between Tyrone and Lewistown, besides a great many highway bridges. Four large railroad bridges over the West Branch of the Susquehanna river were carried away between Lock Haven and Sunbury on the line of the Philadelphia and Erie Railroad, and many smaller structures were destroyed or injured by the flood. These were undoubtedly expected to provide safety for the passage of the greatest volumes of water of which there was any experience, and the destruction of so many of them is evidence of the extraordinary character of the flood. The destruction of one of the bridges on the Juniata seemed due to an accumulation of drift, trees, stumps, and brush above it, closing the waterways and damming up the flood.
>
> "The easterly boundary of the 48.6 square miles of watershed supplying the South Fork reservoir is the

summit of the Allegheny mountains. The rainfall was much greater on the easterly than on the westerly slope. The observations indicate an average rainfall of 6.64 inches on the easterly and 2.76 on the westerly, and it is obvious that except for the failure of the South Fork reservoir dam, the damage caused by the flood would have been less on the western than on the eastern slope.

"Subsequently to their visit to the dam, the Committe viewed the line of the Pennsylvania Railroad from South Fork Station to Johnstown, a distance of about nine miles. It follows the Conemaugh river, which flows in a deep valley. The average descent is about 33 feet per mile, the maximum grade being 52.8 per mile, but the river, being more circuitous, is about three miles longer, its descent between the same points being substantially the same, or about 300 feet. The rise of the water during the flood was generally about 30 feet; at some points, however, it was considerably more. The flood washed away all the bridges between South Fork Station and Johnstown, except the stone bridge near the Cambria Iron Works, and nearly all the embankments and a great part of the tracks. The greatest destruction was within about five miles of Johnstown. The streams on both sides of the mountain range had risen rapidly during the night between Thursday and Friday, but the waters on the eastern slope had reached their flood height earlier on Friday morning than those on the western slope. Nearly the entire working force of the Western Division of the Pennsylvania Railroad had, therefore, been sent to the Middle Division, and were scattered along the Juniata and Susquehanna rivers, when the breaking of the South Fork Reservoir dam on Friday afternoon suddenly caused the destruction of the railroad in the Conemaugh Valley with a fearful loss of human life and in the annihilation of private property amounting in value to millions of dollars. All the means of communication between the inundated sections of the country had been destroyed, and the only reliable line of access for the immediate relief to the flooded districts in the vicinity of Johnstown was from the west. When on Saturday morning the full extent of the disaster became known, prompt measures were at once adopted by the public authorities and voluntary

organizations for the relief of the sufferers and for substantial assistance to the distressed.

"We are informed by the Secretary of the Flood Relief Commission that their records to January 11th, 1890, show that there are known to be lost in the Conemaugh Valley by the flood of May 31st, last, 2,280 persons. Bodies are recovered from time to time as excavations are made in the debris, and it is possible that a number of persons may have been drowned of whom there is no trace, as there was a considerable floating population in the Valley, but from the best information we can obtain, we think the total loss of life by the flood did not exceed 2,500. We have found it impracticable to obtain definite information of the loss of property caused by the flood, but as the result of recent inquiries of persons, in official positions and having the best opportunities of knowing, we estimate the loss by individuals and corporations as between three and four millions of dollars."

The flood was most severe on the streams draining the eastern slope of the Allegheny. Bridges were destroyed on the Juniata and Susquehanna rivers, and the canals bordering these streams were damaged beyond repair. It would be impossible to estimate approximately the financial loss along these streams. None of the western rivers reached unprecedented height except the Conemaugh.

The Conemaugh river and Stony creek before the breaking of the dam were at a high stage, submerging the greater part of the city of Johnstown under about four feet of water, and preventing residents escaping from their houses. When the dam broke the water previously held behind it, being added to the already swollen streams, increased to twelve feet the depth of the water over the city, and the loss of life amounting to nearly 2,500 in and around Johnstown was the result of the sudden onrush of this great body of water, which gave no opportunity for the victims to take refuge on higher ground. The property loss in this region was estimated as between $3,000,000 and $4,000,000. A maximum rate of run-off of 200 second feet per square mile from the 48.6 square miles of drainage area above the South Fork dam was determined by the American Society of Civil Engineers Committee to have been the discharge at the dam previous to its destruction.

PITTSBURG FLOOD.

The flood of March 14th and 15th, 1907, the worst the Pittsburg region has experienced, is remarkable in many ways. The height

of all three rivers, Allegheny, Monongahela and Ohio, at their junction at Pittsburg, was greater than previously recorded, while the damage to property and estimated losses are reported as exceeding that done at any one point by floods in Pennsylvania. The entire lower portions of both Pittsburg and Allegheny were under several feet of water for many hours. Industry was at a standstill, railroads flooded and street cars put out of operation.

The extraordinary height of the rivers at Pittsburg was caused chiefly by floods in the Monongahela river, coincident with high water in the Allegheny. The latter stream, however, was not at unprecedented height for the stage of 24.6 recorded at Freeport, 25 miles above Pittsburg, had been previously exceeded, the maximum flood recorded in the last thirty years having been eight feet higher than that on March 15th, 1907. The Kiskiminetas river was, however, nearly to record height, and was responsible for the stage reached by the lower Allegheny. The Youghiogheny river was at unprecedented height and was largely responsible for the great flood in the lower Monongahela river.

Continuous warm rains and the melting of considerable depth of snow concentrated over the region drained by these two tributaries, and extending more or less continuously over the whole western section of the State, was the original cause of the flood, while the deforested condition of the watershed of the Kiskiminetas and the Youghiogheny probably assisted a rapid run-off and consequent high stage.

Since no remarkable or extraordinary conditions caused this flood, and since the Clarion (a most variable stream), Kiskiminetas and the Youghiogheny, drain but 4,825 square miles, out of a total of 18,500 square miles tributary to the Allegheny and Monongahela rivers at Pittsburg, or only 26 per cent. of the total area, (on which three streams besides the long continued rain, a very considerable but not unprecedented amount of melting snow occurred) the possibilities of the future, when conditions existing over the whole are similar to those which prevailed over this 26 per cent., are not reassuring. The tributary drainage basins of the other streams in this region are not so depleted of forests or so highly developed industrially as those feeding the Kiskiminetas and Youghiogheny rivers, but the tendency is in that direction.

It is well again to reiterate and emphasize that in this, the greatest and most disastrous flood from a financial view point which Pennsylvania has experienced, none of the usual elements that cause floods was predominant. There was not heavy, long continued rain, it was not extraordinary warm for the season of the year, causing unusual rapid melting of the snow, there was not a record breaking depth of snow on the ground, and the rivers were not seriously choked by ice gorges.

PLATE 7.

Mouth of Monongahela River at Pittsburg during flood of March, 1907.

PLATE 12.

Turtle Creek, at East Pittsburg, Allegheny County, during flood of March, 1907. High stage in creek caused by back water from Monongahela River.

PLATE 8.

Mouth of Beaver River at Rochester during flood of March, 1907.

That greater floods may be expected at Pittsburg is suggested by a comparison of the records of the Ohio and Susquehanna rivers. These two streams drain at Wheeling, W. Va., and at Harrisburg, Pa., respectively, 23,800 and 24,030 square miles, areas approximately equal. If conditions of rainfall, forest cover, topography, geology, development and industry were alike in the two basins, flood discharges approximately equal at these two points might be expected. The Susquehanna drainage basin is subject to a rainfall of 41 inches, while the Ohio basin receives 41.2 inches. The topography does not differ essentially, each stream having certain tributaries leading from the glaciated areas and regulated by lakes, ponds and swamps, and both draining the sides of the Allegheny mountains, through other tributaries. The records show that the great rain of May and June, 1889, resulting in a run-off at Harrisburg, in the Susquehanna river, of 29.2 cubic feet per second per square mile,, while during the flood of March, 1907, the Ohio at Wheeling reached but 20 cubic feet per second per square mile. What a discharge of 30 cubic feet per second per square mile at Pittsburg would mean in damage and loss of life cannot be foretold.

Table No. 22 shows the stage of the three rivers at Pittsburg, and at points above and below, during this flood for two days before and three days following the arrival of the crest at Pittsburg. The previous maximum stage recorded at each station is also given to show the relative height reached during the flood of 1907, as compared with that during the greatest previous flood. On the Allegheny river at Herr's Island, and on the Monongahela river at Pittsburg, the 1907 flood exceeded all other, being 2.7 feet higher on the Allegheny river and 3.9 feet higher on the Monongahela river than the previous maximum stage recorded. It will be noticed that the Allegheny river at Freeport, the Conemaugh river at Johnstown, the Kiskiminetas river at Salina, and the Monongahela river at Lock No. 4, have all been higher during past floods than they were during that of March, 1907.

TABLE No. 22.

Stages at Flood Warning Stations on Allegheny, Monongahela and Ohio Rivers During the Flood of March, 1907.

Station.	River.	13	14	15	16	17	18	Prev. max. stage.	Date of prev. max.
Franklin,	Allegheny,	1.3	8.0	8.4	8.8	8.2	8.3	.....	
Clarion,	Clarion,	3.5	8.0	8.5	6.9	6.5	5.8	15.2	May 21, '94.
Freeport,	Allegheny,	9.7	24.4	24.6	16.5	.....	14.2	32.7	At mouth of Kiskr. R.
Johnstown,	Conemaugh,	9.4	18.0	9.0	6.5	5.8	5.8	21.0	Trib. to Kisk. R.
Saltsburg,	Kiskiminetas,	5.0	18.6	13.4	6.0	5.0	4.5	18.5	Feb. 19, '91.
Aspinwall,	Allegheny,	24.6	37.5	42.6	38.9	.....	27.0	.....	6 mi. abv. mouth.
Herr's Island Dam,	Allegheny,	13.2	31.6	36.4	23.6	17.2	15.3	33.7	Mar. 2, '02.
Lock No. 4,	Monongahela,	21.0	37.4	35.0	22.6	15.5	12.6	42.0	July 11, '88.
West Newton,	Youghiogheny,	7.9	26.3	21.9	10.5	7.6	6.6	22.0	Jan. 22, '04.
Pittsburg,	Monongahela,	12.7	31.1	35.8	22.8	15.7	13.4	31.9	1884.
Davis Island Dam,	Ohio,	13.0	29.1	33.7	22.2	15.5	13.7	30.3	Feb. 18, '91.
Wheeling, W. Va.,	Ohio,	17.5	37.9	47.8	48.9	.....	27.9	.....	

The highest water in the large rivers of Pennsylvania usually occurs in January, February, March or April, with an occasional flood during the other months of the year. Of the 102 high water periods noted below on the Delaware, Susquehanna, Allegheny and Monongahela rivers, 13.7 per cent. occurred in January, 23.5 per cent. occurred in February, 24.5 per cent. in March and 11.7 per cent. in April. This is due in large measure to the melting snow over the tributary drainage area, ice gorges and the saturated condition of the soil. Some general influence acting over a large area must exist in order to cause extraordinarily high water in a great river, and it is seldom that a heavy rain, like that of May and June, 1889, prevails over such a vast territory. The Monongahela river rose to its greatest flood height on July 11th, 1888, as a result of heavy rains and the Youghiogheny at Confluence on August 21st, 1888, but such instances are exceptional.

RECORDS OF NOTABLE FLOODS.

Extraordinary circumstances may occur accompanied by unavoidable calamity of which no adequate warning can be given by State or National authority, but reasonable precaution may be taken to safeguard life and property from ordinary floods. Before adopting protective measures it is essential that a thorough knowledge of the past performances of streams should be known, and because the subject of flood preventions is a new one, this Commission has thought it advisable to make a thorough statement of the floods in the main river valleys of Pennsylvania; so certain facts with reference to the Delaware, Schuylkill, Susquehanna, North and West Branches, the Allegheny, Monongahela and the Ohio rivers are herein given.

DELAWARE RIVER.

The following table, No. 23, taken from page 65, Water Supply and Irrigation Paper No. 162, shows the gauge height and discharge of the Delaware river at Lambertville, N. J., during largest floods from 1786 to 1905:

TABLE No. 23.

Floods on Delaware River at Lambertville, N. J.

(Drainage Area, 6,855 square miles).

Year.	Date.	(a) Gauge height (feet.)	Discharge (sec ft.)
1786	October 6,	16.0	175,000
1801		14.0	140,000-150,000
1814		14.0	115,000
1832	March,	12.0	115,000
1836	April,	14.5	140,000-150,000
1839	April,	14.6	140,000-150,000
1841	January 8,	20.0	254,600
1843	October 13,	14.0	140,000-150,000
1846	March 15,	17.6	207,000
1862	June 8,	.....	223,600
1891	January,	.....	109,100
1900	March 2,	12.0	87,250
1901	December 16,	18.9	158,300
1902	March 2,	20.2	171,700
1903	March 1,	13.6	103,700
....	October 11,	24.5	250,000
1904	February 22,	15.1	.....
1905	March 28,	11.9	86,220

(a) Heights given for 1786 to 1846 are heights above low water. See report New Jersey Geological Survey for 1894, vol. 3, p. 235: and Report of Chief Engineer U. S. Army for 1873, App. U. p. 19. Discharges have been computed from the gauge heights given.
(b) Due to ice gorges.

According to the records appearing in the above table the greatest flood on this stream since 1786 occurred January 8th, 1841, during which the rate of flow was 254,600 second feet, or 37.1 second feet per square mile of drainage area. The largest in recent years was the flood of October, 1903, the rate on the 11th being 250,000 second feet. The storm that produced this flood on the Delaware river caused an unprecedented flood on the Passaic river, in northern New Jersey. The table indicates more frequent floods on this stream since 1900, which is due partly to the fact that since 1897 daily record of the river stage has been kept, so that all floods are recorded, while previous to that date, only data of floods of magnitude were preserved.

Floods on this stream, although frequent in occurrence, have not caused such extensive losses as freshets on other rivers in the State, owing probably to the fact that the densely populated portion of the valley of this stream is near its mouth, where the river is broad, and hence its height less affected by the quantity of water passing. On the upper part of the stream the banks are generally high, and towns and industries have usually been located out of reach of all but exceptionally high water, but during the flood of October, 1903, severe losses were caused. It will be noticed from the above and succeeding records, that extremely high stages

PLATE 9.

Delaware River at Matamoras, Pike County, during flood of March 1902. This bridge was carried out by the flood of October, 1903.

are of less frequent occurrences on the Delaware than on the Susquehanna or Ohio rivers.

SCHUYLKILL RIVER.

The valley of the Schuylkill river, the largest tributary of the Delaware, has been subject to repeated inundation as indicated by Table No. 24, which shows the flood record at Fairmont dam, on the Schuylkill river in Philadelphia:

TABLE No. 24.

Floods on Schuylkill River at Fairmount Dam. Philadelphia, Pennsylvania. (Drainage area, 1,915 square miles).

Year.	Date.	Discharge in second feet.
1899	February 28,	18,045
1900	February 23,	21,798
	March 2,	19,061
1901	February 11,	25,744
	December 16,	24,025
	December 30,	29,662
1902	January 22,	37,901
	March 1,	82,156
	December 17,	30,180
1903	March 1,	29,874
	April 15,	19,520
	October 10,	29,986
1904	January 23,	27,210
	February 22,	22,810
	March 8,	26,180
	September 15,	29,490
1905	January 7,	30,190
	March 21,	23,160
1906	March 4,	27,025
	June 19,	19,978

The greatest flood during the terms of this record was that of March 1st, 1902, when the discharge reached the rate of 42.9 cubic feet per second per square mile of tributary drainage area, a volume twice as great as that during any other flood of which data has been obtained. Heavy losses were caused to railroads, canals, municipalities and manufacturing plants throughout the entire valleys. The next largest flood, January 22nd, of the same year, had a discharge only half as great as that in March. Closely approaching that of January 22nd, 1902, was the flood of March 8th, 1904. The flood of March, 1906, reached a height of 14 feet above its normal level at Pottstown, inundating the city and cutting off its communications with other points by washing out railroads, trolley and wagon roads, and carrying away bridges. In this storm the rainfall in the vicinity of Pottstown reached 3 inches during the afternoon and evening of March 3rd, but the flood did not assume extraordinary proportions at Philadelphia. The regimen of the Schuylkill river has been seriously affected by deforestation in the coal regions around its headwaters, and as a

result the congested population and industries in its valley have suffered.

SUSQUEHANNA RIVER.

The following table, No. 25, shows the daily stage and rate of flow of the Susquehanna river at Harrisburg, during the floods that have occurred from 1865 to 1907:

TABLE No. 25.

Floods on Susquehanna River at Harrisburg, Pennsylvania, 1865-1907.

(Drainage area, 24,030 square miles; danger line 17 feet gauge height).

Year.	Date.	Gauge Height.	Discharge second feet.
1833	May 14,	.....	.....
1865	March,	.....	(a)
1875	March 18,	14	(b)
1875	April 4,	16.5	(b)
1878	December 12,	18.5	(b)
1881	February 13,	18.	(b)
1884	February 8,	14	(b)
1884	February 15,	15.75	(b)
1886	January 6,	17.5	(b)
1886	February 13,	19.5	(b)
1886	April 2,	14.5	(b)
1886	April 8,	14.5	(b)
1889	June 2,	26.1 (b)	670,000 to 735,000
1891	February 19,	19.0	234,500
1894	May 22,	25.6	540,720
1898	March 24,	15.6	244,740
1901	December 16,	21.4	404,800
1902	March 2,	23.9	483,760
1903	March 2,	16.8	276,500
1904	March 8,	23.3	.....
1905	March 21,	15.7	283,700

(a) Approximately the same as during the flood of June, 1889.
(b) Stages from private records of William A. Kelker, Harrisburg, Pa.

Five phenomenal floods are recorded in table No. 29, those of March, 1865, June, 1889, May, 1894, March, 1902, and March, 1904. Three of these, in March, were due to rapid melting of snow and to ice gorges, and the other two, occurring later in the year, were due to rainfall alone. The flood of June, 1889, when a large part of the city of Harrisburg was under water, had, at that point, a maximum rate of discharge of from 28 to 30.6 second feet per square mile of drainage area. The storm causing this flood was general over a large portion of the State and lasted about thirty-four hours, during which time from four to nine inches of rain fell on the drainage basin. This flood reached a stage of 33.5 feet above low water at Williamsport on the West Branch, while the highest stage at that point during the flood of 1865 was 27 feet. The Chemung river, a tributary of the North Branch of the Susquehanna, with a drainage area of 2,055 square miles, reached a maximum rate of flow at Elmira on June 1st, of 67 second feet per square mile. No

PLATE 10.
Ice flow on Susquehanna River at Harrisburg during flood of March, 1904.

authentic record is available of the height of the river during the flood of March, 1865, but old residents state that it reached about the same proportions as that of June, 1889.

The flood of 1904, at Harrisburg, was remarkable for the extent of the ice flow as well as for the height reached by the water. The primary cause of this flood was the breaking up of the ice in January without enough water flowing to force it down the river. Gorges were formed at various points along the stream and its branches, which were solidified by exceptionally cold weather in the following month. When the final break came these gorges were augmented and acted as dams, impounding a large quantity of water. On March 6th and 7th there were heavy rains all over the drainage area, and on March 6th, the resulting floods broke through the various barriers, and finally forced the big gorges at Highspire and Bainbridge, wiping out islands and doing much damage in its course. After the flood subsided at York Haven the gorge moved to Turkey Hill, where it stood for several hours and backed the water to within a few feet of the Columbia bridge. This gorge in turn gave way and moved to Shenks Ferry where it gorged for the last time. Although it held here for only a few moments it raised the water and ice 6 feet above the railroad tracks at Safe Harbor, completely destroying the stone arch bridge and leaving ice throughout the village to the height of the second story windows.

The elevation of the crest of the flood, as compared with the June flood of 1889, varied in height along its course as shown by Table No. 26:

TABLE No. 26.

Comparison of Heights of Floods of 1889 and 1904 on Susquehanna River.

Location.	Height above sea level in 1889	Height above sea level in 1904	Remarks.
New Cumberland,	311.7	309.5	2.2 ft. lower in 1904.
Marsh Run,	306.4	307.7	1.3 ft. higher in 1904.
Middletown Ferry,	304.8	305.3	0.5 ft. higher in 1904.
Goldsboro,	296.8	300.8	4.0 ft. higher in 1904.
Falls Station,	290.4	299.7	9.3 ft. higher in 1904.
York Haven,	277.5	292.4	14.9 ft. higher in 1904.
Three-fourths mile south of York Haven,	276.0	289.0	13.0 ft. higher in 1904.
Goose Run,	273.5	283.7	10.2 ft. higher in 1904.
New Holland,	272.0	272.8	0.8 ft. higher in 1904.
Codorus Bridge,	270.0	271.0	1.0 ft. higher in 1904.
Columbia,	242.3	243.9	1.6 ft. higher in 1904.
Washington,	231.0	237.4	6.4 ft. higher in 1904.
Cresswell Station,	229.0	235.1	6.1 ft. higher in 1904.
Safe Harbor,	.....	210.8	3 ft. higher in 1904.
York Furnace,	.....	.....	3 ft. higher in 1904
McCall Ferry,	.....	.....	3 ft. lower in 1904
Head of Cullys Falls,	.....	.....	About the same in 1904 as in 1889.

With the flood wave came a large amount of ice from 3 to 10 feet in thickness, as shown by the blocks left on the shores. Owing to the cross currents in the river the greater portion of the ice went down on the York county side, and it was on this side that most of it was left piled up on the shores. The channel on the Lancaster county shore soon cleared itself, and but little ice accumulated upon that bank except at certain spots.

The gorge at Turkey Hill broke in the afternoon of the 8th, and the water reached a maximum height at McCall Ferry, reported as 161.3 feet above sea level on the Lancaster county side, and 159.8 feet on the York county side. Within half an hour from the time the maximum height was reached the water had fallen from 2 to 3 feet, and on the morning of March 9th it had fallen 15 feet. Between Shenks Ferry and Port Deposit no more ice jams were formed, and the ice passed through the channel of the river very rapidly and caused but little damage.

The full effect of the flood on the main stream was not felt below Sunbury, being restrained by the big gorges at Kipps Run, Catawissa and Nanticoke, which held several days longer. It was at its worst in Wyoming Valley on the 9th, doing much damage to Plymouth, Wilkes-Barre and Pittston.

A rough estimate of the damage caused by this flood has been placed at $8,000,000 involving property as far up the river as Pittston city. The damage to State bridges alone was reported at $800,000.

The cable gauge stations, about ¾-mile above McCall Ferry, offered a good opportunity for determining the amount of water flowing at the maximum stage. At this point two cables are stretched across the river 80 feet apart, and at the time of the flood the sun was shining in line with these and bright enough to cast their shadows on the white ice, thus enabling the determination of velocity at this point with considerable degree of accuracy. The velocity was measured in four different portions of the river and several individual observations were made in each portion. According to this measurement the mean velocity was 11.6 feet per second and the river discharge was 631,000 cubic feet per second.

The report of the Pennsylvania Canal Commissioners for 1833 states that the flood of May 14th, 1833, was one of the highest known in the Susquehanna river for many years. The North Branch rose at Wilkes-Barre 28 feet above low water and covered the canal for 9 miles down from Nanticoke dam, carrying away a lock house. On the West Branch the water rose to an unusual height, making two breaches in the canal. Below Sunbury several bridges were destroyed and Shamokin dam at Sunbury was endangered. Penns creek which comes in from the North, 6 miles

PLATE 11.

Middletown, Dauphin County, during flood in Susquehanna River of March, 1904.

below the dam, rose suddenly and swept away the canal embankment at its mouth. Below Sunbury the damage was slight. The repairs to the canals made necessary by reason of the damage caused by this flood occupied one month.

WEST BRANCH SUSQUEHANNA RIVER.

Floods have been a vital question at Williamsport, on the West Branch of the Susquehanna river, so much damage resulting that in 1895 a commisison was appointed which, after a thorough investigation, made a report to the city, recommending means for the protection of that city against floods. This commission was assisted by examinations made by Major Raymond, Corps of Engineers, United States Army, and the late L. Y. Shermerhorn, Civil Engineer. The commission found that "an annual charge of $5.00 per lot or less (in the city of Williamsport) for a limited number of years will guarantee perpetual immunity from floods carrying five feet more of water than the highest one ever known," but no action was taken on the part of the city to carry out these recommendations.

The greatest floods on the West Branch of the Susquehanna river were in 1865 and 1889, and table No. 28 exhibits the height of the water at various points on this stream during these periods. That of 1865 was caused by the rapid passing away of snow and ice after a severe winter, and its amplitude was probably increased by ice gorges. The flood of 1889, which exceeded all preceding flood limits, was due to the heavy rain of May 31st and June 1st, which caused the Johnstown flood. The principal parts of the cities of Lock Haven and Williamsport were under from four to eight feet of water, and along the West Branch 78 lives are known to have been lost. No attempt was made to secure even the approximate estimate of the financial damage resulting from this flood.

Table No. 27 shows the dates of and heights reached by the largest floods in the West Branch at Williamsport. The heights of the floods of 1865 and 1889 are taken from the Williamsport Flood Protection Report, p. 12, and the zero upon which they are based is probably a few feet lower than that of the permanent gage established in 1896, from which the rest of the table is measured. These two floods were, therefore, recorded several feet higher than they would have been had they been referred to the zero of the present age.

TABLE No. 27.

Floods on West Branch of the Susquehanna River at Williamsport.

(Drainage area 5,640 square miles).

Year.	Date.	Height.	Discharge.
1865	March,	27.0	.....
1889	June 1,	33.5	.....
1896	Mar. 31,	13.9	76,800
1898	Mar. 24,	21.0	162,600
1900	Nov. 27,	17.0	110,100
1901	Apr. 22,	15.2	89,900
	May 30,	14.0	77,500
	Dec. 15,	20.17	150,900
1902	Mar. 2,	21.38	164,100
	Apr. 10,	16.6	105,500
1903	Feb. 4,	16.0	93,100
	Mar. 1,	17.07	110,700
1904	Mar. 4,	19.0	135,100
	Mar. 24,	18.0	124,000
	Apr. 2,	16.8	107,800
1905	Mar. 20,	18.4	130,000

TABLE No. 28.

Stages of Floods of 1865 and 1889 along the West Branch of the Susquehanna River.*

Locality.	Distance from mouth.	Elevation above ordinary low water.	
		March, 1865	June, 1889
Mouth of West Branch,	.....	.....	.....
Northumberland,	8	20	18
Muncy Dam,	31	30	37
Williamsport,	49	27	33.5
Lock Haven,	75	14	18
Clearfield,	.....	10	17

*From Williamsport Flood Protection Report, p. 12.

NORTH BRANCH SUSQUEHANNA RIVER.

The following table shows the daily stage and rate of flow of the North Branch of the Susquehanna river at Wilkes-Barre during the large floods that have occurred from 1899 to 1907:

TABLE No. 29.

Floods on the North Branch of the Susquehanna River at Wilkes-Barre.

(Drainage area 9,310 square miles).

Year.	Date.	Gauge Height.	Discharge.	Year.	Date.	Gauge Height.	Discharge.
1899	Apr. 10,	14.2	49,600	1902	Mar. 2,	30.75	217,700
	Apr. 15,	14.3	50,100		Mar. 18,	20.20	97,100
1900	Jan. 22,	16.85	68,800		Dec. 23,	17.65	75,100
	Feb. 23,	16.1	63,200	1903	Mar. 1,	20.4	98,900
	Mar. 2,	17.75	75,900		Mar. 25,	21.16	106,100
	Nov. 28,	20.75	102,200		Oct. 11,	21.25	106,900
1901	Mar. 12,	18.80	84,700	1904	Jan. 24,	18.20	79,600
	Mar. 28,	21.40	108,400		Feb. 9,	25.30	*75,100
	Apr. 8,	18.05	78,400		Mar. 9,	30.6	*108 700
	Apr. 22,	18.10	78,800		Mar. 27,	22.9	123,400
	May 31,	17.55	74,300	1905	Mar. 26,	23.4	130,300
	Dec. 16,	26.75	166,300	1906	Apr. 1,	17.7	79,000

*Discharges reduced 50 per cent. on account of ice gorges.

The valley of the North Branch of the Susquehanna has suffered more in recent years from flood disaster than the main stream or the West Branch, the greatest damage occurring usually between Wilkes-Barre and the forks at Northumberland. The city of Wilkes-Barre has been repeatedly inundated, and municipal and federal authorities have made investigations looking toward relief, without remedial results. The conditions in this stream are probably the result of deforestation and conditions similar to those in the Schuylkill drainage basin. Even in a record over such a short term as the above an increase in the height of floods and in the frequency of extraordinary stages is apparent. The greatest floods on this stream were those of March, 1902, and March, 1904, during which two floods $1,300,000 worth of bridges and millions of dollars of property were destroyed.

ALLEGHENY RIVER.

The following table shows the daily stage of the Allegheny river at Freeport during the large floods that have occurred from 1874 to 1906 inclusive:

TABLE NO. 30.

Floods in Allegheny River at Freeport.

Date.	Stage.	Date.	Stage.
Jan. 8, 1874,	18.6	May 24, 1894,	24.5
Apr. 3, 1875,	20.8	Apr. 10, 1895,	20.6
Dec. 27, 1875,	19.6	Mar. 31, 1896,	20.2
Feb. 12, 1876,	19.0	Mar. 24, 1898,	25.3
Dec. 11, 1878,	23.0	May 24, 1900,	22.1
Mar. 12, 1879,	22.7	Nov. 27, 1900,	21.7
Feb. 13, 1881,	20.6	Apr. 21, 1901,	23.0
June 10, 1881,	29.4	Dec. 16, 1901,	21.4
Jan. 28, 1882,	23.0	Mar. 1, 1902,	28.8
Feb. 5, 1883,	30.5	July 4, 1902,	20.0
Feb. 17, 1883,	20.0	Feb. 5, 1903,	23.5
Feb. 6, 1884,	30.0	Mar. 1, 1903,	23.0
Mar. 13, 1884,	21.0	Jan. 23, 1904,	21.2
Jan. 6, 1886,	20.0	Mar. 8, 1904,	23.9
Feb. 12, 1887,	24.0	Apr. 2, 1904,	25.6
Feb. 18, 1891,	32.7	Mar. 20, 1905,	32.0
Feb. 8, 1893,	22.5	Mar. 15, 1907,	24.6
May 18, 1893,	22.0		

As shown by this table, the greatest floods on this stream at Freeport were those of June 10th, 1881; February 5th, 1883; February 6th, 1884; February 16th, 1891; March 1st, 1902; January 23rd, 1904; March, 1905 and March 15th, 1907; but the latter flood, which reached a stage of 24.6 feet at Freeport, had been exceeded by nine previous floods during the term of the record. Table No. 31 shows the height reached during the 1905 flood at various points of the watershed of the Allegheny river.

TABLE NO. 31.

Stages along Allegheny River during Flood of March 18-31, 1905.

Date.	Freeport (a).	Oil City (a).	Redhouse, N. Y.	Redbank Creek, Brookville, Pa. (a).	Clarion River, Clarion, Pa. (a).	Conemaugh River, Johnstown, Pa. (a).
March 18,	10.0	4.2	6.5	1.4	7.4	6.4
March 19,	16.8	15.5	11.4	5.0	10.8	7.6
March 20,	31.2	17.6	11.6	5.8	16.0	8.8
March 21,	28.5	14.9	11.7	4.0	11.0	9.0
March 22,	26.3	14.1	11.1	3.8	9.6	7.0
March 23,	21.5	12.3	9.9	2.8	7.7	5.4
March 24,	18.0	11.1	9.6	2.0	6.8	4.5
March 25,	17.4	11.0	9.6	.....	.....	.....
March 26,	16.8	10.8	9.7	.....	.....	.....
March 27,	17.5	10.4	9.9	.....	.....	.....
March 28,	18.0	10.3	9.8	.....	.....	.....
March 29,	15.0	9.4	9.3	.....	.....	.....
March 30,	13.0	8.6	8.8	.....	.....	.....
March 31,	11.8	7.9	8.2	.....	.....	.....

(a) United States Weather Bureau Station.
(b) Maximum, 32 feet.

port were those of June 10, 1881; February 5, 1883; February 6,

At Freeport, at the mouth of the Kiskiminetas river, a height of 32 feet was recorded on March 20th, 1905, which was only 0.7 feet below the highest water recorded at that point during 33 years which the records have been kept; this highest water being on February 18th, 1891. During the flood of 1865 the water rose to a height of 21 feet at Oil City, 134 miles above Pittsburg, while during the flood of March, 1905, it reached a height of 17.6 feet. At Kittanning, Armstrong county, the United States Geological Survey has maintained a gaging station, which showed during the flood of 1905 a maximum discharge, on March 20th, of 240,900 cubic feet per second in the Allegheny river. At this time the gauge height was 28.8 feet, which was 26.5 feet above ordinary low water, and was only 6 or 8 inches below the height reached by the flood of 1865. The maximum rate of discharge reached 27.7 cubic feet per second per square mile over its drainage area of 8,690 square miles. The Ohio river at Davis Island dam, five miles below Pittsburg reached its maximum recorded height previous to the flood of March, 1907, during the flood of February, 1894, which flood rose to 32.3 feet at this point. During the flood of March, 1905, the height of 27.1 feet was recorded at Davis Island dam.

MONONGAHELA RIVER.

The following table gives the daily rate of flow of the Monongahela river at Lock No. 4, during all the large floods from 1886 to 1907, inclusive:

TABLE NO. 32

Floods on Monongahela River at Lock No. 4.

(Drainage Area, 5,430 square miles.)

Year.	Date.	Gauge Height.	Discharge.
1885	April 1,	27.0	92,600
	April 7,	26.0	85,800
	May 15,	24.3	75,600
1887	February 4,	31.0	120,600
	February 27,	28.0	99,600
1888	July 11,	42.0	207,000
1889	February 18,	27.0	92,600
	June 1,	25.0	79,800
1890	February 21,	23.5	70,800
	March 23,	31.8	126,200
	October 14,	24.3	75,600
1891	January 3,	31.3	122,700
	February 11,	24.0	73,800
1892	January 15,	28.5	103,100
1893	January 30,	23.5	70,800
1895	January 8,	30.0	113,600
1896	July 31,	25.3	81,600
1897	February 23,	36.0	159,000
1898	January 11,	23.9	73,200
	March 25,	24.7	78,000
1899	March 6,	26.9	91,900
1900	November 27,	33.8	141,400
1901	April 21,	25.5	82,800
	December 16,	28.5	103,100
1902	January 28,	25.9	85,200
	March 1,	29.5	110,100
	December 14,	26.2	87,000
1903	February 17,	28.4	102,400
	March 1,	32.5	131,100
1905	January 12,	24.3	75,600
	March 11,	29.3	108,700
	March 22,	27.2	94,000
1907	March 14,	27.4	*172,000

*Estimated.

The greatest flood during the term of this record was that of July 11th, 1888, when a stage of 42 feet was reached, resulting from a heavy rain of comparatively short duration, causing a discharge of 207,000 cubic feet per second, which was at the rate of 38.1 second feet per square mile. The flood of March 15th, 1907, caused by rain and melting snow, the second greatest flood at this point, reached a stage of 37.4 feet. The third greatest flow was that of February 23rd-24th, 1897, when a 36 foot stage was reached, furnishing a flow of 159,000 second feet, or 29.3 second feet per square mile.

OHIO RIVER FLOODS AT PITTSBURG.

The following table, No. 33, gives the stages reached by the floods at Pittsburg from 1872 to 1907 inclusive. High water at this point results from floods in the Allegheny or in the Monongahela river, or from coincident floods in both. By comparison with the table of floods on those rivers it will be seen that large floods at Lock No. 4 and at Freeport did not always result in correspondingly high

water at Pittsburg, and that some of the most serious floods at the latter point were not extraordinarily high farther up on the rivers.

TABLE NO. 33.

FLOODS AT PITTSBURG.

Junction of Ohio, Allegheny and Monongahela Rivers.

(Drainage Area, 18,500 square miles.)

Year.	Date.	Gauge Height.	Year.	Date.	Gauge Height.
1872	Apr. 11,	19.0	1891	Feb. 18,	31.3
1873	Jan. 6,	20.2	1892	Jan. 15,	22.9
	Dec. 14,	24.5	1893	Feb. 8,	23.1
1874	Jan. 8,	22.2	1894	May 22,	22.5
1875	Mar. 16,	20.5	1895	Jan. 8,	25.7
	Aug. 3,	21.0		Apr. 11,	20.2
	Dec. 28,	20.8	1896	Mar. 31,	20.6
1876	Sept. 19,	20.8	1897	Feb. 24,	28.9
1877	Jan. 17,	22.1	1898	Mar. 24,	28.5
1878	Dec. 11,	23.4	1899	Mar. 6,	22.0
1880	Feb. 14,	21.6	1900	Nov. 27,	27.7
1881	Feb. 13,	21.5	1901	Apr. 8,	21.0
	June 10,	25.1		Apr. 21,	27.4
1882	Jan. 28,	21.5		Dec. 16,	25.8
1883	Feb. 8,	26.8	1902	Mar. 2,	30.3
	Feb. 16,	20.7		Apr. 10,	20.6
1884	Feb. 6,	31.9	1903	Jan. 31,	20.8
1885	Jan. 17,	22.0		Feb. 5,	23.5
1886	Jan. 6,	20.2		Mar. 1,	28.9
	Apr. 7,	22.2	1904	Jan. 23,	30.0
1887	Feb. 12,	21.9		Mar. 4,	26.5
1888	Jan. 8,	21.3		Apr. 2,	21.9
	July 11,	21.3	1905	Mar. 22,	29.0
1889	June 2,	21.8	1907	Jan. 19,	23.5
1890	Mar. 24,	22.5		Mar. 15,	25.8
1891	Jan. 3,	23.0			

Six great floods have occurred at Pittsburg; namely, those of February, 1884; February, 1891; March, 1902; January, 1904; March, 1905; and March, 1907; and it will be noticed that four of these have come in the last six years. During the flood of 1904 it is reported that about $1,000,000 worth of property was destroyed in Western Pennsylvania and Eastern Ohio. The flood of 1905 resulted from the rapid melting of snow from March 16th to 20th, and a rain-fall of 1.25 inches in two days. Ice gorges also assisted in raising the height of this flood.

Table No. 33 shows that from 1872 to 1890, 19 years, the 25 foot stage was exceeded but three times, while in the 17 years following, this stage was exceeded thirteen times.

In some localities in the State the maximum flood record established many years ago has not been exceeded, but the high stages are much more frequent in latter years, each flood approaching if not exceeding the previously established high water mark. This is more marked on some of the western rivers where the records

cover a long term of years and extend back over a period when extensive deforestation was in progress over their watersheds.

STATE EXPENDITURES.

Since 1897 the Commonwealth has expended large sums of money in rebuilding county bridges which have been destroyed by floods. The Act under which this work is done was approved June 3rd, 1895, and amended April 21st, 1903. Up to June, 1907, a total of $2,839,809 had been paid by the State under its provisions. Since 1899 there has been expended $400,000 a year merely for the repair of damage done by floods, which represents the interest on $10,000,000 at 4 per cent. Had this $10,000,000 been applied in seven years to work for the control of the floods it is fair to assume that by this time the annual cost for bridge repairs and damage to property and industries along the rivers would have been reduced. The latter damage exceeds many times the cost of bridges and should be materially reduced. Table No. 35 shows a total of nearly $2,000,000 expended upon the Susquehanna and tributaries, about 70 per cent. of which was for structures on the North Branch above Sunbury.

TABLE NO. 34.

Annual Expenditure by State in Re-Building County Bridges Destroyed by Floods.

Year.	Expenditure.
1896,	.....
1897,	$83,300
1898,	9,500
1900,	36,750
1901,	26,810
1902,	966,150
1903,	68,300
1904,	1,093,831
1905,	527,065
1906,	105,994
1907,	*1,500,000
Total,	$4,417,788

*Appropriated in 1907 for two years.

TABLE NO. 35.

Annual Expenditure by State on Susquehanna River in Re-Building County Bridges Destroyed by Floods.

Year.	Expenditure.
1897,	$83,300
1898,	9,500
1899,	.....
1900,	.....
1901,	26,800
1902,	539,500
1903,	14,000
1904,	472,300
1905,	527,065
1906,	40,000
1907,	122,000
Total,	$1,834,465

TABLE NO. 36.

Expenditure by State in Rebuilding County Bridges Destroyed by Floods—Classified by Rivers.

1. Delaware river above Easton, all on tributaries,		$213,700
2. Lehigh river, all on main river,		357 700
3. Schuylkill river, all on main river,		38 700
4. Susquehanna river, below forks, all on tributaries:		
Shamokin creek,	$14,000	
Penn's creek,	121,500	
Conewago creek,	72,700	
Conestoga creek,	70,000	
Total,	.....	278,200
5. Juniata river, total for main stream and tributaries,		177,700
On main stream,	$154,200	
6. West Branch Susquehanna river, all on tributaries,		151,000
7. North Branch Susquehanna river, total for main stream and tributaries,		1,297,800
On main stream,	680,200	
8. Allegheny river, total on main stream and tributaries,		221,800
On Kiskiminetas river,	65,600	
Clarion river,	36 700	
9. Monongahela river,		None.
10. Ohio river,		None.
11. Beaver river, total on main stream and tributaries,		202,800
On main river,	107,800	
Shenango,	23,700	
Conoquenessing creek,	81,300	

RUN-OFF.

Floods result from rapidly melting snow, sudden local rains commonly known as "cloud bursts," ice gorges and other obstructions which cause a rise in the streams, long continued rains, and a combination of rain and melting snow. Small streams may rise suddenly with sharp local showers, quickly assuming flood proportions, while a large river nearby may show little change. To materially effect the height of water in a large stream conditions existing over a considerable portion of its drainage basin or some obstruction to its flow are necessary.

The United States Weather Bureau maintains stations upon the larger streams of the State, where daily record of the river stages are made. These records have been read at 37 points in Pennsylvania, and at 4 points immediately without the State. At Pittsburgh and Freeport on the Allegheny, Confluence on the Youghiogheny, and Harrisburg on the Susquehanna, these records cover over thirty years, while at other points they extend over shorter terms. This Commission is collecting records of stream discharges at each of the 17 measuring stations which have been from time to time established in this Commonwealth. Some of these stations are coincident with those of the Weather Bureau established by the Federal Government for the purpose of forcasting the coming of floods, with a view towards reducing the loss of life and destruction of property occasioned thereby, and in those the records of that organization are not duplicated. Data covering past years are studied and from this knowledge indications of the coming of floods shown by the river stage are telegraphed from the stations, giving warning to shippers and to industries bordering

the streams, allowing preparations to be made for the protection of these interests. These records, when plotted and arranged in form for comparison and study, are of value in devising means for the control of flood waters. Tables have been prepared of the dates and heights of the extreme floods on rivers in Pennsylvania, and through them the character of the streams is shown. All other available records of this nature have been collected and plotted in diagramatic form by the Commission.

The most satisfactory and accurate method of stating the stream flow is in cubic feet of water flowing each second from each square mile of the tributary drainage area, as by this means comparisons upon a unit basis can be made between streams. The flood run-off per square mile decreases as the tributary drainage area increases.

The following tables, Nos. 37, 38 and 39, show certain extraordinary rates of run-off from small streams in New York during 1905, supplemented by data collected from various sources for Pennsylvania and New Jersey streams.

TABLE NO. 37.

Rates of Flood Run-off on Small New York Streams.

Stream and Place.	Drainage area—Square miles.	Date.	Maximum rate—Second feet per square mile.
Mill brook near Edmeston, N. Y.,	9.4	Sept. 3-4,	241
Mad brook near Sherbourne, N. Y.,	5.0	Sept. 3-4,	262
Starch Factory creek near Utica, N. Y.,	3.4	Sept. 3,	209
Starch Factory creek near Utica, N. Y.,	3.4	June 21,	190
Six Mile creek near Ithaca, N. Y.,	46.0	June 21,	195

TABLE NO. 38.

Rates of Flood Run-off on Small Pennsylvania Streams.

Stream and Place.	Drainage area—Square miles.	Date.	Maximum rate—Second feet per square mile.
South Fork Conemaugh river at South Fork Reservoir,	48.6	June 1, 89,	200
Burgoon Run at Altoona Reservoir,	8.0	June 1, 89,	400
Brush creek, near Jeanette, Westmoreland Co.,	6.0	July 5, 1903,	160
Perkiomen creek at Frederick,	152	Feb. 28, 1902,	116
Neshaminy creek,	139	Feb. 6, 1896,	136
Tohickon creek,	102	Feb. 28, 1902,	139
Spring creek,	11.6	Feb. 15, 1908,	260

TABLE NO. 39.

Rates of Flood Run-off on New Jersey Streams.*

Stream and Place.	Drainage area—Square miles.	Date.	Maximum rate—Second feet per square mile.
Passaic river,	823	Oct. 10, 1903,	43.5
Raritan river,	879	Sept., 1882,	60.0
Ramapo river,	160	Sept., 1882,	66
Wanaque river,	101	Sept., 1882,	66
Pequannock river,	85	Sept., 1882,	52.4
Rockaway river,	121	Oct. 10, 1903,	62.5
Pompton river at Pompton Plain,	380	Oct. 10, 1903,	74.6

*Geological survey of New Jersey, 1894.

Table No. 40 summarizes the maximum flood flows per square mile at the gauging stations on the principal rivers of Pennsylvania, and illustrates the reduction in run-off per square mile with the increase in area of drainage basin.

TABLE NO. 40.

Rates of Flood Run-off on Principal Rivers of Pennsylvania.

Stream and Place.	Drainage area—Square miles.	Date.	Maximum rate—Second feet per square mile.
Delaware river at Lambertville, N. J.,	6,855	Oct. 11, 1903,	36.5
North Branch Susquehanna river at Danville,	11,100	Mar. 3, 1902,	27.5
West Branch Susquehanna river at Williamsport,	5,640	Mar. 2, 1902,	29.0
Susquehanna river at Harrisburg,	24,030	June 2, 1899,	29.2
Juniata river at Newport,	3,476	Mar. 1, 1902,	33.8
Allegheny river at Kittanning,	8,690	Mar. 20, 1905,	27.8
Ohio river at Wheeling, W. Va.,	23,800	Feb. .. 1884,	20.0
Chemung river at Elmira, N. Y.,	2,055	June 1, 1889,	67.0
Monongahela river at Lock No. 4, Penna.,	5,430	July 11, 1888,	38.1
Youghiogheny river at Confluence, Pa.,	782	Aug. 21, 1888,	59.0
Schuylkill river at Philadelphia, Pa.,	1,915	Mar. 1, 1902,	42.9

The above information has been inserted in this report for ready reference to those municipalities which may become engaged in the study of local measures for the prevention of floods.

DISCUSSION.

In New York a State Commission made studies of methods for reducing freshet damage, based upon surveys and detailed reports with reference to the improvement of conditions on individual streams, some of which works are being carried out. In New Jersey the recommendation of a flood commission for a large storage reservoir for flood prevention on the Passaic river will probably be followed by the early construction of works involving the expenditures of several million dollars. In some western states storage reservoirs have been constructed to catch and hold the melting snows of spring and distribute the stream flow evenly throughout the year, for irrigation purposes as well as for flood prevention. Vast sums have been expended on the Mississippi river in confining the stream within its banks in times of flood, by the construction of dikes, straightening the channel, etc., and in March, 1907, President Roosevelt recognized the gravity of the situation in the United States by the appointment of a Commission, one of whose duties is the study of floods and methods of their prevention and alleviation. Some of the great rivers of the European
have also been improved for the prevention or reduction of flood damage and for navigation.

RECOMMENDATIONS.

This Commission recommends the placing of the flood control work under the direction of a central State authority, to prepare

a comprehensive scheme of co-operation and concerted action by municipalities and public and private corporations. Protective measures such as dikes, walls, local straightening of channels, etc., sometimes effective, fail in that they do not reach the source of the trouble. The State should lead the way toward correcting as far as possible the causes of the floods.

Certain flood conditions may be ameliorated by the reforestation of the denuded forest areas of the State, by the construction of extensive storage reservoirs upon tributaries of rivers, and by straightening, widening and deepening stream channels. By such means it may be possible to prevent the increasing frequency and damage of floods, but such works must necessarily be extensive. Dams impounding large quantities of water would have to be erected; the flow from them to be so controlled that at periods when floods might be expected, the reservoirs would be at least partially emptied and ready to receive the flood water. The first work of this nature in the State is soon to be commenced at Harrisburg, where considerable damage has resulted from the floods in Paxton creek, a stream which passes through the city, draining an area of 23 square miles. Plans are being prepared by the city for the construction of a storage reservoir, to be located about five miles above the creek mouth, to catch and hold the flood flow, with gates so operated as to allow the passage of a more uniform quantity of water throughout the year.

CHAPTER VII.

WATER POWER.

Under the general laws establishing and defining the duties of the Water Supply Commission, all charters of water power companies must receive its approval and under the Act approved May 28th, 1907 (P. L. 299), detail plans and specifications and such other information and data as may be required, of any dam, wall, wharf, etc., to be erected or extended in or along any public or navigable river or stream heretofore declared a public highway, within the Commonwealth, shall be submitted to and approved by the State Water Supply Commission.

Since the organization of this Commission in June, 1905, seven charters for hydro-electric companies have been granted, involving a development of approximately 20,000 horse-power. These charters are for the construction of central power stations on the Susquehanna river, or its tributaries, for the supply of electrical energy at points within a radius of 25 to 50 miles of the source of power. Since 1895, when the General Corporation Act of 1874 was amended to admit of the formation of water power companies, there have been 73 such corporations organized. Their charters cover municipal districts in all parts of the State, but the majority are located in the Central and Eastern parts.

These companies have purchased or merged with one another to a considerable extent, the records showing 5 mergers, involving 16 charters; and two consolidations by purchase of rights and franchises, involving 8 charters. Of the 73 charters issued, but 17 have been found, by the investigations of the Commission, to be generating and distributing power by virtue of the rights so granted.

Prior to 1900 ten water power companies only had been incorporated. In the years 1900 and 1901 fifteen; in 1902, twenty-one; and in 1903 and 1904, fifteen companies were incorporated. The large number organized in 1902 were for proposed operations on the lower Susquehanna river, some of which were subsequently absorbed by larger companies.

In the earlier development of the State many mills, furnaces and industrial plants were located with a view to the utilization of the flowing streams for mechanical power. In later development, owing to the augmented capacity of and to the relative cheapness of coal as fuel for the generation of steam power, the water power plants decreased in numbers and many of them were entirely abandoned. There are, however, over 1,500 water power privileges

PLATE 13.

Typical abandoned water power mill, Pequea Creek, Lancaster County.

in operation in the State today, principally on the secondary streams.

Recent strides in the knowledge of economic transmission of electric currents make it possible to develop such power at a distance and transmit it many miles to the consumers; and there may be expected in Pennsylvania a material increase of applications for charters for hydro-electric power companies.

There are few natural water falls of magnitude on the larger streams of Pennsylvania. The profiles of the rivers are comparatively straight lines broken by riffles, and occasionally by large rapids; as at Bethlehem on the Lehigh; Foul Rift and the falls above Trenton on the Delaware river; Cullys Falls and Conewago Falls on the Susquehanna; Ohiopyle on the Youghiogheny; and Beaver Falls on the Beaver river. Therefore, to obtain the required head upon the power wheels, it is necessary to build dams, wing-walls or long canals, by which the natural slope of the stream may be concentrated at one point. In this manner much of the water power available on the streams of Pennsylvania must be generated, and the examination of the plans for such projects will be an important part of the work of this Commission.

There existed at one period a considerable amount of water power developed along the canals in Pennsylvania. Mill owners rented the privilege of developing power from various canal owners and built mills at locks and overflow points along the banks of the canal, using the fall at the lock, or from the canal level, to that of the stream whose bank the canal followed. With the abandonment of the State canals the water powers thereon have been destroyed, although some on the existing canals are still in operation, and are being enlarged, as on the Lehigh, Schuylkill, and Bristol and Easton canals. When the water resources of the State have been thoroughly developed, it will necessarily include many water power plants.

The Commission invites attention to the fact that at the time provision was made for the establishment of State Forest Reservations, one of the advantages expected to accrue was the preservation and protection of the streams rising in or traversing such reservations. It has been found impossible, however, for the State to grant the right to cross these lands with flumes, conduits, canals, roads, transmission lines, or to flood any part of them for water storage purposes. An incorporated water power company requested the right, and offered payment therefor, to conduct a flume or canal through State Forest lands along the Little Juniata river, by which means a high head could have been obtained for the development of water power from that stream. It was ascertained that

the Forestry Reservation Commission had no authority under the law to grant such a right. During the past year two water power propositions, which involved the flooding of some State Forest lands, were disapproved on similar grounds.

This Commission recommends that if the General Assembly should determine it to be requisite for the fullest and best development of the water power now going to waste in the State Forest Reservations to permit and provide for the construction of storage reservoirs and appurtenances therein, this work should be done under the supervision and subject to the approval of the proper State departments.

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